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Energy Analysis of Secondary Material Use in Product Manufacture

California State Solid Waste Management Board
Sacramento

Prepared for

California Energy Resources Conservation and
Development Commission, Sacramento

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Regis D. Kunz, and Mark R. Emmerson.

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This study was prepared by the California State Solid Waste Management Board (SSWMB) under contract with the California State Energy Resource Conservation and Development Commission (ERCDC). The funding was made available by the Department of Energy to the ERCDC to support development of California's Energy Conservation Plan. As part of this plan, the report quantifies the savings from energy conservation in California by the efficient management and use of solid wastes and recyclable materials.

KEYWORDS: *Solid waste management, *Waste recycling, *Energy conservation.

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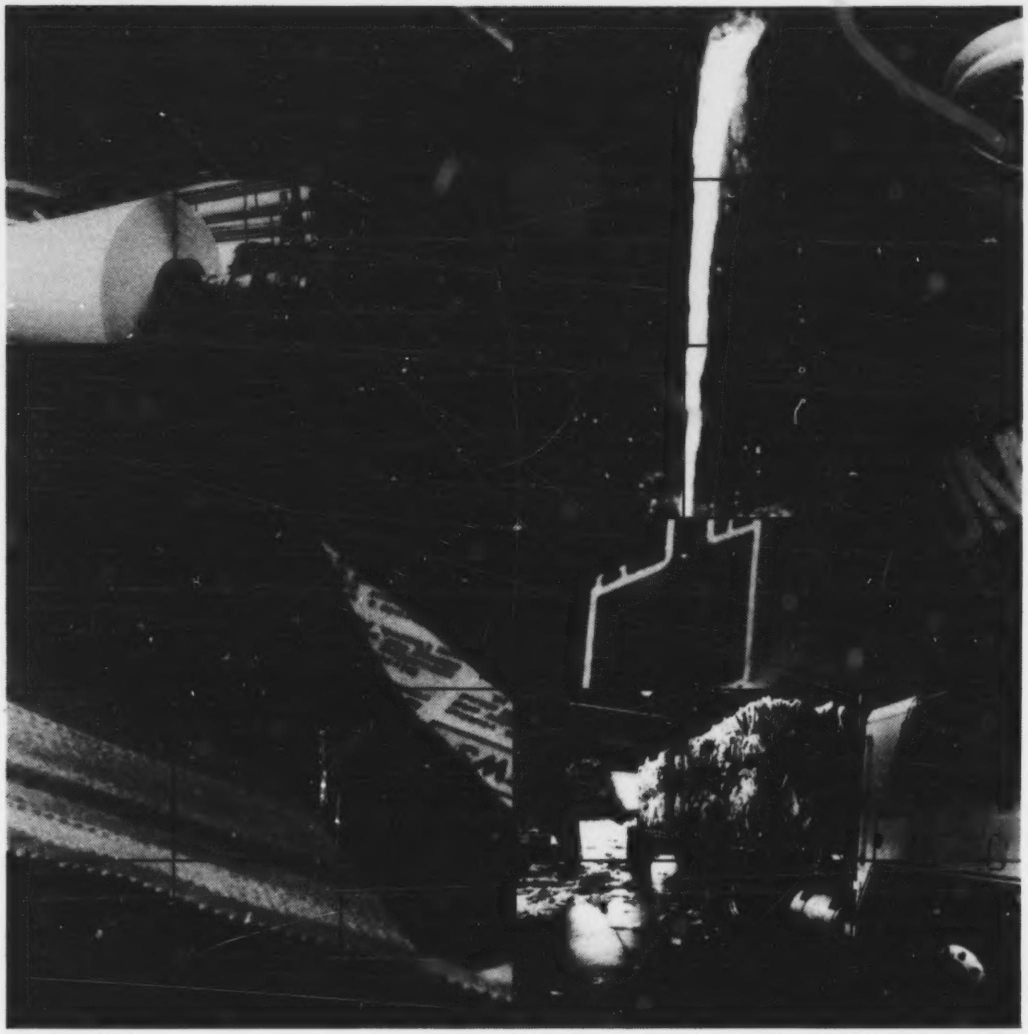

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Resource Conservation
and Recovery Division

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State Solid Waste
Management Board

Prepared for
the Energy Resources
Conservation &
Development Commission

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ENERGY ANALYSIS OF SECONDARY MATERIAL USE IN PRODUCT MANUFACTURE

Regis D. Kunz
Mark R. Emmerson

November, 1979

Resource Conservation & Recovery Division
State of California
Solid Waste Management Board

This work was supported by the California
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FOREWORD

This study was prepared by the California State Solid Waste Management Board (SSWMB) under contract with the California State Energy Resource Conservation and Development Commission (ERCDC). The funding was made available by the Department of Energy to the ERCDC to support development of California's Energy Conservation Plan. As part of this plan, the report quantifies the savings from energy conservation in California by the efficient management and use of solid wastes and recyclable materials.

The project was developed along the lines of five separate tasks. Task I addressed the relative energy requirements of specific recycling mechanisms, the energy requirements of processing secondary materials, the energy requirements of transporting secondary materials to market and to the ultimate point of use after collection, and the relative energy cost of secondary materials use versus virgin materials use. In Task II, the dollar cost of conserving energy via various recycling mechanisms including labor and capital-intensive systems, was identified. In addition, costs associated with the transport of secondary materials to markets in the State were quantified. Task III analyzed the secondary materials market capacity. Further, Task III identified factors influencing the current market capacity which can be affected by legislative or administrative action. Task IV addressed the comparative energy costs of various solid waste collection operations with the intent of minimizing energy consumption. And finally in Task V, conclusions were drawn on the results of the above tasks, and recommendations were made regarding the enhancement of source separation and energy conservation in California.

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The report was supported by the California State Energy Resources Conservation and Development Commission, particularly Mr. Richard Nordahl.

SUMMARY

The purpose of this report is to identify the opportunities for energy conservation by the management of solid wastes in California. In particular, the energy conservation potential presented by the recovery of materials and their subsequent reintroduction to the manufacturing process is specifically addressed and quantified. Although other studies have defined the energy savings gained through returning certain secondary materials to the manufacturing process, none have been specific to California, and few have identified the energy costs associated with the collection and transport of both virgin and secondary materials to the manufacturer. This report has been prepared, therefore, with the goal of identifying these energy costs and the variables impacting the effectiveness of recycling efforts in California.

Source Separation Energy Consumption/Conservation Analysis

The first task to be undertaken was that of estimating the relative energy consumption of the use of secondary materials compared to the use of virgin materials in product manufacture. The materials selected for analysis were glass, aluminum, newsprint, and ferrous metals. Analysis of energy savings were prepared for each of these materials in the manufacturing processes as well as the energy cost of general material handling.

An intensive review of literature was conducted in order to determine the availability of data on energy consumption in product manufacture. Studies isolating each aspect of product development, i.e., mining, transport, etc., were identified and evaluated for applicability. Based on these findings, surveys and interviews were conducted with those parties involved in product development in California. Data were collected through direct contact for two purposes:

1) To determine if the data found in the nationwide studies could be applied to California; and

2) To provide data on those energy-consuming steps not addressed in the literature.

The scope of the energy analysis section includes identifying and quantifying the fuels used in the manufacturing process. Both "primary" energy sources (gasoline, natural gas, and diesel fuels used directly in mining, transport, and manufacture) and "secondary" sources of energy (electricity and steam) are considered in the analysis. The energies associated with labor, manufacture of equipment, and primary fuel production are not considered. Energy consumption was estimated for recovery and processing of recyclables into like products - containers into containers, newsprint into newsprint.

This report addresses residential and commercial sources of refuse only. Recyclable materials were considered to be in the form of glass, ferrous and aluminum containers, and newspaper. "Obsolete" scrap such as junked autos, discarded appliances, and demolition scrap was not considered.

Energy Conservation Cost Analysis

The second major task is an analysis of the costs of various methods of resource recovery. Specifically, this portion of the report deals with transportation costs and the relative costs of five different resource recovery operations: integrated curbside collection, separate curbside collection, "buy-back" recycling centers, "drop-off" recycling centers, and capital-intensive front-end recovery systems processing a heterogenous waste stream.

Information necessary for this analysis was obtained from a literature survey of recycling operations and techniques, a review of the State Litter Control, Resource Recovery, and Recycling Act (SB 650) grant proposals, and personal contact with various existing recycling operations around the State. Different composites were developed for the various transportation and recycling systems. Prices were obtained for the components of each system and, in some cases, costs were estimated by analytical techniques (e.g., regression analysis). Overall cost effectiveness was determined for each composite recycling system and relative comparisons were drawn.

Operational models were developed for processing and handling materials and cost determinations were made. The cost for transporting recovered materials to market was analyzed using private, rental, and PUC regulated carriers. Revenues and costs were expressed in 1978 dollars.

Identification of Secondary Materials Market Capacity and Variables Affecting That Capacity

Crucial to the success of any resource recovery venture is the marketing of recovered materials. It is, therefore, a third task of this project to identify secondary materials market capacity and the variables affecting that capacity. For this purpose, an investigation was made into the attitudes of buyers of recycled materials; specifically, the market performance of ferrous metals, aluminum, glass cullet and fiber (wastepaper) was assessed. The role of the State Solid Waste Management Board in California is also discussed with respect to programs which have been considered by the Board and those upon which the Board has decided to act.

Energy Conservation Opportunities in Solid Waste Collection and Transfer

The final task of this project is the analysis of energy conservation opportunities which exist in the collection and transfer of solid waste. Analysis of these opportunities included factors influencing energy expenditures in collecting, such as vehicle design and routing. In addition, the energy requirements for garbage collection versus those for recycling were compared.

Conclusions and Recommendations

The report concludes that significant energy savings may be realized from the recycling of glass, aluminum and newsprint in California. Potentially, an energy savings of 8.6%, or 1.16×10^6 Btu/ton may be realized from recycling glass, 66.0%, or 206.87×10^6 Btu/ton from recycling aluminum, and 21.4% or 4.55×10^6 Btu/ton from recycling newsprint. No energy savings were projected from the recycling of ferrous cans because of an insufficient demand for the product as a material source for producing new ferrous cans.

The cost analysis concluded that, for a given volume of recyclables processed, there is an optimum method of recycling. For throughput volumes of 10 to 50 TPM, the community drop-off center is the only cost-effective system. For throughput volumes over 100 TPM, the most cost-effective system is integrated curbside collection with aluminum buy-back. The other systems, in order of their cost-effectiveness, are: multi-material buy-back, integrated curbside collection without buy-back, separate curbside collection with aluminum buy-back, and separate curbside collection without buy-back. Break-even points and profit/volume relationships for each type of recycling center were calculated.

It was also concluded that vehicle ownership is the most cost-effective method of material transport for recycling centers when the distance traveled is great and throughput tonnage is high. The point of indifference for recycling center transportation costs using a center-owned vehicle, a rented vehicle, or PUC-regulated carrier has been calculated for buy-back centers.

Conclusions for high-technology resource recovery facilities indicate that such facilities would incur a net cost of $10 to $20 per ton of waste. Such a system could be economically acceptable in areas with comparable solid waste disposal costs.

Market analysis concludes that the ferrous scrap market consists mainly of secondary scrap dealers and the steel can processors. The aluminum market is expected to remain economically attractive, the primary buyers being secondary aluminum manufacturers. Glass cullet markets exist in the primary glass manufacturing industry, but manufacturers appear reluctant to buy from a sole supplier. The fiber market appears to be quite volatile, because of seasonal and cyclical variations; however, long-term demand appears stable.

Energy conservation opportunities in solid waste collection and transfer were found to be of limited significance, in view of the overall energy requirements of processing secondary materials for remanufacture. However, there are opportunities for energy conservation through efficient design and use of collection vehicles and routing techniques.

Recommendations contained in this report deal with methods of encouraging recycling in order to realize energy savings. Included are recommendations for program development by the State Solid Waste Management Board for processes, design, and type of recycling facilities, for transporting material to market and for the role of the State Solid Waste Management Board in facilitating backhauling of waste materials.

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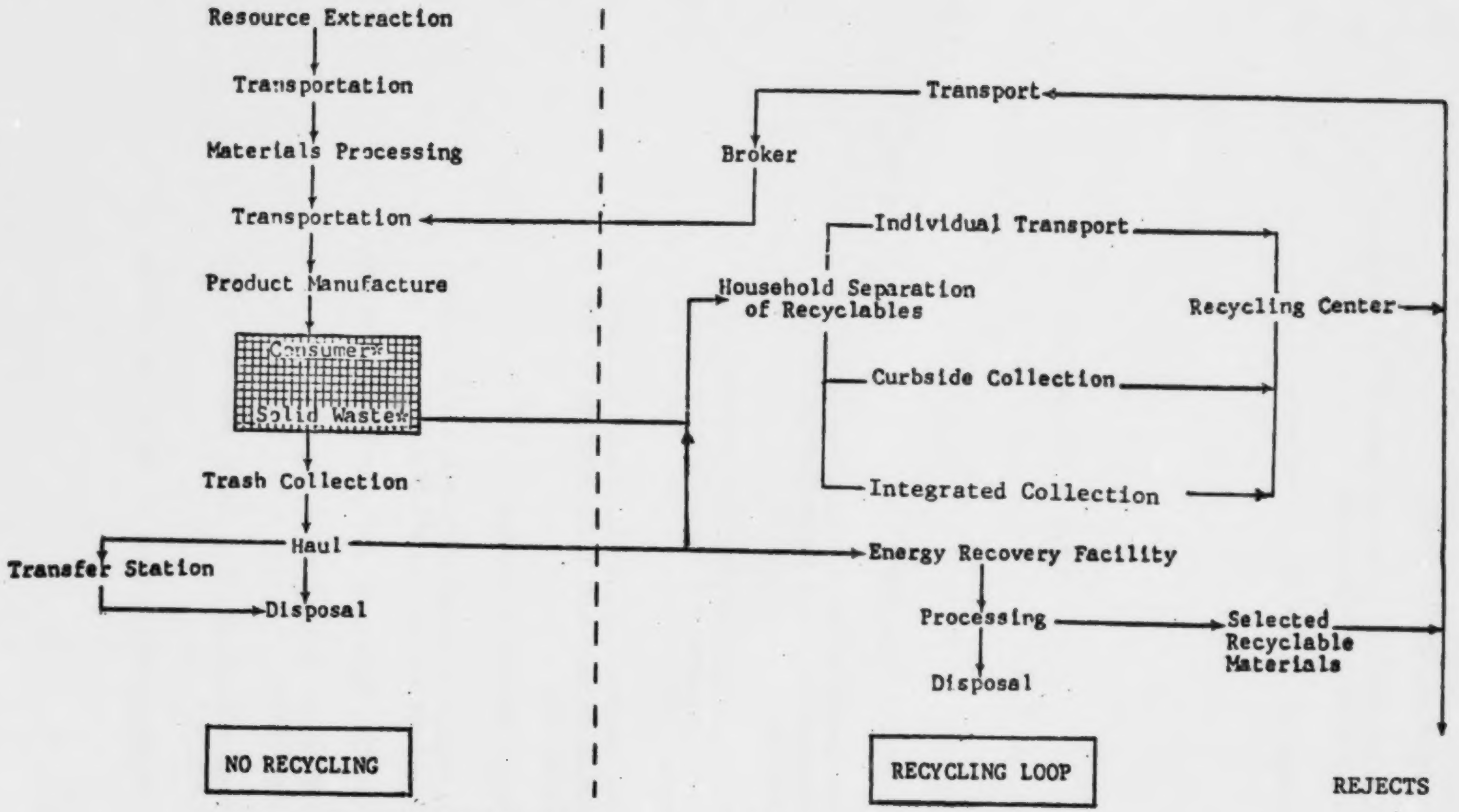
FIGURE 1

MATERIALS FLOW CHART


Resource Extraction
Transportation
Materials Processing
Transportation
Product Manufacture
Consumer*
Solid Waste*
Trash Collection
Haul
Transfer Station
Disposal
Transport
Broker
Individual Transport
Household Separation of Recyclables
Recycling Center
Curbside Collection
Integrated Collection
Energy Recovery Facility
Processing
Selected Recyclable Materials
Disposal
NO RECYCLING
RECYCLING LOOP
REJECTS

*Consumer Use and Solid Waste are shown to illustrate the flow of materials but are not included in the calculations of energy consumption. It is assumed the energy consumed in these activities is unrelated to the use of secondary materials.

CHAPTER ONE
SOURCE SEPARATION ENERGY CONSUMPTION/CONSERVATION ANALYSIS

I. Introduction

The purpose of this chapter is to estimate the relative energy consumption of secondary materials use versus virgin materials use in product manufacture. In order to make the comparison, energy use in the process was grouped into definable steps, e.g., mining of virgin materials, transporting the materials, and garbage collection. Figure 1 is a materials flow chart outlining the discrete variables that were used to identify energy consumption.

The left portion of the chart represents the energy demands in processing virgin materials. This includes mining of virgin materials, transport, intermediate processing (when applicable), product manufacture, collection, and disposal. The right side of the flow chart represents the energy expended in the recycling process. It includes the energy expended in the collection, processing, and transport of recyclables for reintroduction into product manufacture.

Section 2 through 5 are organized to identify the energy consumed at each step as shown in Figure 1. To the extent possible, for each commodity, an energy value is assigned to each step as it applies to California. The information presented in this chapter has been derived from the literature and from direct contact with various industry representatives.

II. General Methodology

A. Approach

An extensive review of literature was conducted in order to determine the availability of data on energy consumption in product manufacture. Studies that isolated each aspect of product development, i.e, mining, transport, etc., were identified and evaluated for their applicability to this study. Numerous reports discussed national energy consumption averages and tendencies for developing products from virgin materials. None were specific to California and few addressed energy consumption in recovering and utilizing secondary materials.

Based on these findings, surveys and interviews were conducted with those parties involved in product development for California. References throughout this report indicate information received from literature and information received from direct contact with the involved parties. Data were collected through direct contact for two purposes:

1. To determine if the data found in the nationwide studies could be applied to California; and

2. To provide data on those energy consuming steps not addressed in the literature.

B. Standardized Conversion Factors

The next step was to integrate the data received in order to determine the relative amounts of energy consumed in product manufacture with and without utilization of secondary materials. In performing calculations, various conversion factors were applied. These conversion factors appear in Table 1 and their sources are referenced.

The values in the Table were often found in various references, although only one may be noted. In other cases, the values found in various sources were not consistent. For example, values for transport by waterway ranged from 250 Btu/ton-mile (Battelle, 1975) to 680 Btu/ton-mile (Conservation Foundation, 1973). In these cases, the value that was most representative and best documented was chosen. Of course, there will be a variability for any value; most notable of these are conversion factors for natural gas and electricity.

TABLE 1
CONVERSION FACTORS

TRANSPORTATION		
Rail[1]	720	Btu/Ton Mile
Truck[2]	2,400	Btu/Ton Mile
Barge[3]	540	Btu/Ton Mile
FUELS		
Diesel Fuel[2]	138,000	Btu/gallon
Gasoline[2]	125,000	Btu/gallon
Residual[4]	150,000	Btu/gallon
Distillate[4]	139,000	Btu/gallon
Natural Gas[2]	1,000	Btu/cu.ft.
Fuel Oil[5]	144,000	Btu/gallon
Bark/Chip Fines[6]	10.5×10^{6}	Btu/ton burned
Propane[2]	88,800	Btu/gallon
OTHER		
Electricity[7]	11,100	Btu/kwh
Steam[8]	1,130	Btu/lb.

Footnotes to conversion factors

1. Calculated from 5.25 gallons of diesel fuel/ton mile:
   Robert G. Hunt ., et. al., Resource and Environmental Profile Analysis of Nine Beverage Container Alternatives, Final Report for U.S. Environmental Protection Agency, 1974, Page 49.
   and 138,000 Btu/gallon diesel fuel.
2. Bruce Hannon , "Bottles, Cans, Energy", Environment, Volume 14, No. 2, March 1972, Page 16.
3. Eric Hirst "Energy Intensiveness of Transportation", Transportation Engineering Journal, Volume 99, No. Tel, February 1973, Page 113.
4. E.H. Hall and W.T. Hanna, "Final Report on Evaluation of the Theoretical Potential for Energy Conservation in Seven Basic Industries", for the Federal Energy Administration by Battelle Columbus Laboratories, July 11, 1975, Page 203.
5. National Center for Resource Recovery, Inc., New Orleans Resource Recovery Facility, Implementation Study, September 1977, Page 300.
6. Gordian Associates, The Potential for Energy Conservation in Nine Selected Industries, January 1974, Page 406.
7. Robert G. Hunt, et. al., Resource and Environmental Profile Analysis of Nine Beverage Container Alternatives, Final Report for U.S. Environmental Protection Agency, 1974, Page 17.
8. Gordian Associates, Page 402.

Various conversion factors for natural gas have been identified based on the source of fuel. This detailed information is critical to the industry for specific cases, but an estimate is sufficient for our purposes. Therefore, a value of 1,000 Btu/cubic foot of natural gas was selected.

The conversion factor for electricity is dependent on the type of generation. The conversion factor used, 11,100 Btu/kwh, is a national average energy expenditure of fossil fuels and hydropower required to deliver electricity to the public. This factor takes into account power generation using coal, crude oil, fuel oil, natural gas, nuclear fuel, and hydroenergy. It was not practical to attempt to identify the ratios of fuels used to generate electricity at each step in the development process for each product, so a national average was chosen. The range of values is demonstrated by considering the energy required to generate and transmit electricity using: (1) natural gas, and (2) hydropower. Assuming a generation efficiency of 32 percent and transmission efficiency of 90 percent, electricity generated with natural gas could be delivered to the public while consuming about 11,800 Btu/kwh. Assuming a generation efficiency of 100 percent and a transmission efficiency of 90 percent, electricity generated by hydropower could be delivered to the public while consuming about 3,800 Btu/kwh. Obviously, the source of power is an important consideration in estimating energy consumption values. The nation-wide average was calculated by weighting the conversion factor for each type of fuel by the percentage of U.S. electricity generation contributed by each type of fuel, then averaging the values.

C. Scope of the Study

The type of refuse and products addressed in Chapter 1 are limited by the scope of study. This report addresses residential and commercial sources of refuse only. This excludes "obsolete" scrap such as junked automobiles and discarded appliances. It also excludes construction and demolition debris. Instead, it addresses the refuse produced on a regular basis by residential and commercial sources that could be collected on-site by routine collection. For purposes of this study the recyclable portion of the refuse includes glass containers, ferrous containers, aluminum containers, and newsprint. It is assumed that, in waste composition studies, essentially all glass, ferrous, and aluminum are in the forms of containers. Therefore, the values given in residential/commercial waste composition studies for these products are used directly as the proportions of recyclables.

Additionally, energy consumption is estimated only for recovery and processing of recyclables into like products. For example, the energy consumed in using post-consumer glass containers to make new glass containers is characterized; the energy consumed in using post-consumer glass containers to make glass-wool insulation or terrazzo is not characterized.

Energy consumption, the primary subject of Chapter 1, is limited to the fuels used directly in the development of products. This limitation includes "primary" energy sources, such as natural gas and diesel fuel, used directly in mining, transport, and manufacture. "Secondary" sources of energy, i.e, electricity, are included in terms of the primary energy required to produce them as identified previously. "Ultimate" energy, the energy required to supply the primary energy for each step is not included. Energy to produce the equipment used in each step of product development is not included. Energy consumed by environmental controls is not always identified nor is the energy expended in disposing of the wastes produced at each step of the process. Energy consumed through fuel use, primary and secondary, is the subject of this report whereas identification of opportunities for conservation of fuel as an energy source is the major objective. One method of conserving fuel might be to reduce the amount of refuse produced. This is recognized as a viable potential method of energy conservation, but it is not included in this particular study. Additionally, opportunities for energy conservation in other aspects of solid waste management are not part of this study. This report does not specifically address opportunities for energy conservation in solid waste management for the agricultural or industrial sectors; the scope of this report is limited to residential and commercial sources of refuse and the energy involved in processing this refuse.

SECTION 1 - MATERIAL HANDLING

I. Introduction

There are several options for handling post-consumer refuse; primarily, refuse may be landfilled or may be reused after processing by a recycling center or by a solid waste recovery system. The energy consumed by each of these three options is considered in this section.

II. Methodology

Energy consumed in post-consumer solid waste activities has not been a major topic in literature. In fact, very little information is available. Therefore, data were gathered mainly by direct contact with those involved in these activities. To determine energy expended in landfilling, 12 landfill operations were contacted throughout the State of California. Landfills with varying fill rates were contacted in order to get a representative sample. The majority of landfills contacted were municipally operated because it was felt that the response rate would be higher. Ten of the twelve landfills responded.

In order to determine the energy expended in recycling through recycling centers, energy surveys were conducted on six major recycling centers in Northern California. Wherever possible, data on monthly energy consumption through electricity, gas, gasoline, propane, and diesel fuel were acquired. The monthly throughput of recycled materials, identified as glass, newsprint, aluminum, etc., was requested. Although twelve consecutive months of data were desired for each facility, less was available. From these data, energy expenditures per ton of recycled material was estimated. Fuel consumed by vehicles carrying recyclables to the center and, whenever possible, by vehicles carrying recyclables to market from the center was surveyed. Because of incomplete information available, the energy consumption conclusions from these data must be considered rough estimates.

After an exhaustive literature search for information on recovery by capital-intensive systems, only one report was found that had energy expenditures values based on actual operation. The report, Evaluation of the Ames Solid Waste Recovery System, Part I, Summary of Environmental Emissions: Equipment, Facilities, and Economic Evaluations, was completed in November 1977. The Ames, Iowa system has been operating since August 1975; the report provides information on facility operations in 1976.

III. Landfilling

As mentioned previously, energy expenditures in landfilling were determined by surveying 12 landfills throughout California. Data on annual diesel fuel consumption, gasoline consumption, and fill rates were acquired and averaged as shown in Table 2. Estimates of energy expended in the collection of wastes and at administrative and maintenance facilities were based on a survey.

TABLE 2

ENERGY CONSUMPTION IN LANDFILL OPERATIONS

Landfill	Diesel Consumption ($\times 10^9$ BTU)	Gas Consumption ($\times 10^9$ BTU)	Total BTU/Yr. Cons. ($\times 10^9$ BTU)	Fill Rate (TPY)	BTU/Ton
1	6.8	1.7	8.5	255,010	33,332
2	23.0	3.4	26.0	1,300,000	20,000
3	6.0	-	6.0	67,000	89,552
4	4.4	3.0	4.7	85,000	55,294
5	9.2	0.75	10.0	546,000	18,315
6	2.4	0.13	2.5	181,110	13,804
7	2.6	0.29	2.9	38,000	76,316
8	2.3	0.16	2.5	45,930	54,429
9	1.1	-	1.1	35,690	30,821
10	1.5	-	1.5	256,720	5,843
			Low	35,690	5,843
			High	1,300,000	89,552
			Average	281,045	39,770

Linear correlation of Btu/Yr. vs. Fill Ratio yields a figure of 20,100 Btu/ton. (Correlation = 0.95)

TABLE. 3

ENERGY IN COLLECTION AND TRANSPORT OF REFUSE

		Collection (10 Tons)		Transport	
Vehicle	Trip	Gallons	Miles	Gallons	Miles
1	A	14	25	4.0	20
	B	13	20	4.5	19
	C	12	21	4.0	20
	D	10	19	4.0	20
	E	8	22	4.5	19
2	A	13	20	5.0	20
	B	16	29	5.5	19
	C	12	23	6.5	20
	D	11	19	4.5	20
	E	14	20	6.5	20
Average		12.3	21.8	4.4	19.7
MPG		1.8		4.5	

Collection energy $\frac{12.3 \text{ gal diesel}}{10 \text{ ton}} \times \frac{138{,}000 \text{ Btu}}{\text{gal. diesel}} = .170 \times 10^6 \frac{\text{Btu}}{\text{ton}}$

Transport energy $\frac{4.4 \text{ gal diesel}}{10 \text{ ton}} \times \frac{138{,}000 \text{ Btu}}{\text{gal. diesel}} = .061 \times 10^6 \frac{\text{Btu}}{\text{ton}}$

Total energy $= (.170+.061) \times 10^6 \frac{\text{Btu}}{\text{ton}} = 0.23 \times 10^6 \frac{\text{Btu}}{\text{ton}}$

Energy Consumption

The energy consumed by administrative and maintenance facilities associated with landfill operations is estimated to be 0.014 x 10^6 Btu/ton; this is based on one facility's average energy expenditure of 63 x 10^6 Btu/month and an average landfill rate of 4400 tons/month. The energy expended in collection of refuse is estimated to be 7790 Btu/ton-mile; and, assuming 21.8 miles on-route, 0.170 x 10^6 Btu/ton. These values are derived from data on two 25 yard packers: the mileage and fuel consumption for five trips each (see Table 3); and the energy expended in transport of refuse to the landfill and back, 0.061 x 10^6 Btu/ton. The average energy expended in collection (21.8 miles) and transport (19.7 miles) in this example is 0.23 x 10^6 Btu/ton of refuse. For the ten landfill operations surveyed, the average fill rate was 280,000 TPY. The average energy expenditure estimate, based on annual diesel and gasoline consumption and annual fill rates, was 0.02 x 10^6 Btu/ton.

IV. Labor-Intensive Resource Recovery

Labor-intensive resource recovery, recovery via recycling centers, is separated into four different systems in this study: (1) drop-off at the center by citizens, (2) drop-off at mobile centers with subsequent pickups by the center, (3) curbside collection separate from refuse collection, and (4) integrated recyclables/refuse curbside collection. These different systems determine the energy consumed in collection and transport to the recycling center. Estimated energy consumption in processing at the recycling center is assumed to be the same regardless of the collection system.

A. Drop-off by Citizens

The preliminary value for energy expended in the drop-off system is 2.23×10^6 Btu/ton of recyclables. This estimate is based on the following assumptions. A household delivers 35 lbs/month to the center five miles round-trip from home. (See Appendix D, Section 1-VII). Five miles is an average based on a range of less than a mile round-trip to ten miles round trip. The average vehicle fuel consumption rate is assumed to be 16 miles/gallon of gasoline, the 1978 composite vehicle MPG figure.

B. Drop-off at Mobile Centers

Based on data collected in an energy survey of a recycling facility, an energy expenditure of 0.03×10^6 Btu/ton of recyclables collected was estimated. This estimate is based on an average of 18 trips/month to drop-off centers with vehicles that average 1.67 gallons of gasoline expended/trip and an average of 20 miles round-trip to each drop-off center. If automobiles were included, assuming round-trip of two miles, the additional energy expended would be 0.89×10^6 Btu/ton. The lower distance is assumed because various drop-off centers would provide more recycling opportunities closer to home than only one center in a larger area. The adjusted value is 0.03×10^6 and 0.89×10^6, or 0.92×10^6 Btu/ton recycled.

C. Separate Curbside Collection

Data acquired in surveys of three reycling centers was diverse. Monthly throughputs averaged 650 ton/month (TPM), 500 TPM, and 280 TPM. Collection energy expenditures average 0.232 x 10^6 Btu/ton, 0.098 x 10^6 Btu/ton, and 0.465 x 10^6 Btu/ton respectively. Because of the small number of samples and the wide variety of values, no conclusions can be made. In an attempt to provide comparison with sections, the energy value received from the same facility that provided information on conventional collection is used in this report. That collection and transport energy is 0.232 x 10^6 Btu/ton; the weighted average of the three operations is similar, 0.261 x 10^6 Btu/ton.

D. Integrated Curbside Collection

Although integrated curbside collection, the collection of recyclables on the vehicle collecting refuse, has been tried in California, there is no multi-material integrated collection at present. No data were available on the systems that have been used. The California State Solid Waste Management Board and the Office of Appropriate Technology are co-sponsoring a design competition for a vehicle that would simultaneously collect household refuse and home separated recyclable materials. As the result of this effort and others, a vehicle for integrated collection may become available.

For the purpose of this report, it is assumed that the energy used in integrated collection is identical to that of refuse collection only. It is recognized that there would be additional energy expenditures because of longer idle time while collecting and longer travel distances if the drop-off of recyclables is at a different location than the landfill. Also, collection efficiency of recyclables would be limited if they are not compacted. Because this cannot be quantified, it is not included. Therefore, energy consumption for integrated collection and transport is assumed to be 0.23 x 10^6 Btu/ton of recyclables. (See Table 3).

E. Processing

The average energy expended to process recyclables at a recycling center is estimated to be 0.082 x 10^6 Btu/ton. This value is an average derived from four of the six surveys of California recycling centers. Energy used ranged from 0.06 x 10^6 Btu/ton to 0.11 x 10^6 Btu/ton. There is a variety of processing equipment at these centers. Each facility had at least one forklift, all had an electric paper baler, two had magnetic can separators with conveyance systems, and one had a hammermill. The values also include lighting and heating energy. The average throughput was 402 tons per month; the range was 124 TPM to 836 TPM.

V. Capital-Intensive Resource Recovery

The Ames Solid Waste Recovery system receives municipal solid waste (MSW) and separates the noncombustible refuse from the combustible refuse through the use of machinery. An equipment list, including power ratings, appears in Table 4. The non-combustibles are separated into ferrous metal (7 percent of MSW), non-ferrous metal (0.01 percent), glass and grit (0.6 percent), and rejects to landfill (7.4 percent of MSW). The combustibles are made into refuse-derived fuel (RDF) that is burned with coal to generate electricity. RDF is apparently 84 percent of the MSW; there will be some plant material losses.

Table 5 shows the monthly and annual production of the facility. During the last seven months of 1976, 23,539 tons of refuse were processed and 19,792 tons of RDF with a heating value of 5,610 Btu/lb. were derived; total electric energy generated attributable to RDF was 11,972,000 kwh; and total energy consumption was 1,516,600 kwh. Table 6 shows these values. Because the Ames facility is not located in California and because the Ames facility uses coal in

TABLE 4 MAJOR ELECTRIC MOTORS--REFUSE PROCESSING PLANT AND STORAGE BIN

Conveyor No.[a]	Equipment Served	kW[b]	hp	Name Plate Amperage
	3-Phase 4,160-v motors			
	First stage shredder	746	1,000	151
	Second stage shredder	746	1,000	151
	ADS fan	149.2	200	25.3
	Pneumatic conveying blower--plant to storage bin	149.2	200	26
	3-Phase 460-v motors			
C1	Raw refuse in-feed conveyor	5.60	7.5	11
C2	Shredder No. 1 discharge conveyor	5.60	7.5	11
C3	Shredder No. 2 feed conveyor	7.46	10	14
C4	Backup raw refuse feed conveyor	3.73	5	6.7
C5	Shredder No. 2 vibrating feeder conveyor	7.46	7.5	11
C6	Shredder No. 2 discharge conveyor	1.12	1.5	2.5
	Magnetic belt separator	3.73	5	7.6
	ADS flight conveyor	11.19	15	19.5
	ADS surge bin scalping roll	2.24	3	4.15
	ADS vibrating feeder	7.46	10	14
	ADS rotary airlock	11.19	15	21
	Screw conveyor	14.92	20	24.7
	Rotary airlock feeder for pneumatic conveying to storage	29.84	40	49
	Vane Pump No. 1	2.24	3	4.5
	Vane Pump No. 2	2.24	3	4.5
C7	ADS heavies conveyor	1.12	1.5	2.5
C8	ADS heavies conveyor to E1	1.12	1.5	2.5
C9	Fe-metal conveyor to C13	1.12	1.5	2.5
C10	Rejects conveyor to C11	1.12	1.5	2.5
C11	Rejects conveyor to C3	1.12	1.5	2.5
C12	Fe-metal conveyor to C13	1.12	1.5	2.5
C13	Fe-metal conveyor to storage	1.12	1.5	2.5
C14	Conveyor from E1 to C15	1.12	1.5	2.5
C15	Conveyor to rejects conveyor C16	1.12	1.5	2.5
C16	Rejects conveyor to storage	1.12	1.5	2.5
C17	Glass or rejects to storage	1.12	1.5	2.5
E1	ADS heavies bucket elevator	2.24	3	4.8
E2	Rejects bucket elevator	1.12	1.5	2.5
E3	Glass and rejects bucket elevator	1.12	1.5	2.5
E4	Aluminum bucket elevator	1.12	1.5	2.5
E5	Copper and brass bucket elevator	1.12	1.5	2.5
	Chicago pump	1.12	1.5	2.4
	Air compressor	11.19	15	20.5
	Equipment hoist	11.19	15	20.5
	Equipment trolly for hoist	0.75	1	1.8
	Equipment bridge for trolly	2.24	3	4.6
	Live bottom Hopper No. 1	3.73	5	7.6
	Live bottom Hopper No. 2	3.73	5	7.6
	Trommel screen drive	11.19	15	18.7
F2	Aluminum separation conveyor	0.25	0.33	0.75
F3	Aluminum separation conveyor	0.25	0.33	0.75
C19	Nonferrous separation conveyor	0.25	0.33	0.75
C20	Aluminum separation conveyor	0.37	0.5	1
C21	Aluminum separation rejects conveyor	0.37	0.5	1
C24	Aluminum separation conveyor	0.25	0.33	0.8
C25	Nonferrous separation conveyor	0.37	0.5	1.1
C27	Nonferrous rejects conveyor to C28	0.37	0.5	1
C28	Nonferrous rejects conveyor to E2	0.56	0.75	1.4
F6	Nonferrous separation conveyor	0.25	0.33	0.8
F7	Nonferrous separation conveyor	0.25	0.33	0.8
C29	Glass conveyor to E3	0.25	0.33	0.8
C31	Secondary aluminum separation conveyor	0.25	0.33	0.8
C32	Nonferrous conveyor	0.25	0.33	0.8
	Motor generator (exciter 30 v 5 amp, alternator 222 KVA 0.8 power factor 120/208 v 61.5 amp)	37.30	50	60

(continued)

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TABLE 4 (continued)

Conveyor No.[a]	Equipment Served	kw[b]	hp	Name Plate Amperage
	Storage bin fluffing roll A	2.24	3	4.5
	Storage bin fluffing roll B	2.24	3	4.5
	Storage bin fluffing roll C	2.24	3	4.5
	Storage bin fluffing roll D	2.24	3	4.5
	Storage bin rotary airlock feeder A	5.60	7.5	11
	Storage bin rotary airlock feeder B	5.60	7.5	11
	Storage bin rotary airlock feeder C	5.60	7.5	11
	Storage bin rotary airlock feeder D	5.60	7.5	11
	Blower for pneumatic conveyor to boiler-line A	44.76	60	77
	Blower for pneumatic conveyor to boiler-line B	44.76	60	77
	Blower for pneumatic conveyor to boiler-line C	44.76	60	77
	Blower for pneumatic conveyor to boiler-line D	44.76	60	77
	Paper bailer	37.30	50	62.5
	Paper bailer conveyor	3.73	5	6.7
	Wood chipper	93.25	125	140
	Wood chipper feed	0.56	0.75	1.1
	Wood chipper conveyor	18.65	25	32.0
	Single-Phase 120-v Motors			
C22	Aluminum separation conveyor	0.37	0.5	9.8
C23	Aluminum separation conveyor	0.37	0.5	9.6
C30	Secondary aluminum separation conveyor	0.37	0.5	9.8
	Nonferrous separation conveyor No. 1	0.37	0.5	9.8
	Nonferrous separation conveyor No. 2	0.37	0.5	9.8
	DC 240-v Motors			
	Storage bin sweep conveyor - Drive No. 1	29.84	40	138
	Storage bin sweep conveyor - Drive No. 2	29.84	40	138
	Storage bin drag conveyor A	5.60	7.5	25.8
	Storage bin drag conveyor B	5.60	7.5	25.8
	Storage bin drag conveyor C	5.60	7.5	25.8
	Storage bin drag conveyor D	5.60	7.5	25.8
	DC 90-v Motors			
Nonferrous system	Long belt drive No. 1	0.37	0.5	5.5
Nonferrous system	Long belt drive No. 2	0.37	0.5	5.5
Nonferrous system	Long belt drive No. 3	0.37	0.5	5.5
Nonferrous system	Short belt drive No. 1	0.37	0.5	5.5
Nonferrous system	Short belt drive No. 2	0.37	0.5	5.5
F1	Nonferrous system conveyor 100/200 V	0.75	1	1.2/0.6
	Subtotal	2,460.66	3,298.47	
	Power Supply			
Nonferrous system	Rectifier for magnetic belt separator	15		
	Total	2,475.65		

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a/ Conveyor No. refers to processing flow diagram.
b/ kw Basis 0.746 kw/hp. ASTM Standard E380-74, Metric Practive Guide.

SOURCE: From Municipal Environmental Research Laboratory, Evaluation of the Ames Solid Waste Recovery System, Cincinnati, Ohio, EPA-600/2-77-205, November, 1977, p. 168

TABLE 5 MONTHLY PRODUCTION - AMES, IOWA, REFUSE PROCESSING PLANT

Month (1976)	Raw Refuse Processed	Glass and Grit	Rejects to Landfill	Fe-Metal	Non Fe-Metal	Woodchips	RDF (by Difference)[a]
	Weight (Mg) (1 Mg=1.102 Tons)						
January	2,894.79	28.31	136.22	183.47	0.00	67.80	2,478.99
February	2,719.42	7.24	165.83	176.50	0.00	39.45	2,330.40
March	2,785.70	16.92	278.36	157.75	1.65	29.28	2,301.74
April	3,900.30	56.06	301.42	251.01	1.26	28.96	3,261.59
May	3,476.43	14.08	274.58	236.18	0.00	23.14	2,928.45
June	3,354.01	4.20	261.10	253.43	0.00	28.43	2,806.85
July	3,193.80	56.29	210.40	244.61	0.00	25.06	2,657.44
August	3,314.41	7.67	236.65	226.65	0.00	7.69	2,835.75
September	3,197.65	4.52	237.85	215.98	0.00	12.66	2,724.96
October	3,419.85	22.01	276.41	279.01	0.00	22.06	2,820.36
November	1,739.29	0.00	134.29	133.61	0.00	0.00	1,471.39
December	3,140.88	0.00	249.99	236.49	0.08	11.16	2,643.16
Sub total	21,359.89	94.69	1,606.69	1,589.78	0.08	107.06	17,959.91
Total	37,136.53	217.30	2,763.10	2,594.69	4.67	295.69	31,261.08
Percent	100%	0.6	7.4	7.0	—	0.8	84.2

a/ RDF by difference is incoming raw refuse less glass and grit, rejects, Fe-metal, Non Fe-metal, and woodchips. Therefore, the RDF by difference also includes any plant material losses.

SOURCE: From Municipal Environmental Research Laboratory, Evaluation of the Ames Solid Waste Recovery System, Cincinnati, Ohio, EPA-600/2-77-205, November, 1977, p. 109

TABLE 6 NET ELECTRICAL POWER GENERATION (June 1 through December 31, 1976) (in kw-hr)

Month	Processing plant electric power consumption	Electric power generation attributable to RDF[a]	Net electric power generated	Net electric power generated/mg of raw refuse received[c]
June	189,530	1,680,224	1,490,694	444.5
July	220,255	1,849,345	1,629,090	510.1
August	206,920	1,765,991	1,559,071	470.5
September	222,855	2,001,168	1,778,313	556.2
October	198,625	2,057,143	1,858,518	543.4
November[b]	175,350	985,485	810,135	465.9
December	303,065	1,633,061	1,329,996	432.4
Total	1,516,600	11,972,417	10,445,817	489.1

a/ Based on plant records of monthly amounts of RFD and coal used.

b/ Excludes 2-week period of downtime after fire November 6.

c/ Based on amounts of raw refuse received at processing plant, not Mg of RDF burned.

SOURCE: From Municipal Environmental Research Laboratory, Evaluation of the Ames Solid Waste Recovery System, Cincinnati, Ohio, EPA-600/2-77-205, November, 1977, p. 94

part to generate electricity, it is not an entirely suitable example for California. Furthermore, the boiler in use during the EPA analysis had a heat rate of approximately 16,500 Btu/kwh on 100 percent coal. The ultimate use of RDF is intended to be in an adjacent suspension fired boiler having a heat rate of 12,500 Btu/kwh. A study by SCS Engineers on Bay Area waste composition found the average heating value of organics and other burnable material from the MSW to be around 4800 Btu/lb, this includes a moisture content of 40%. (See Appendix D, Section 1-VII).

The Ames data, however, can be used to calculate net energy produced using RDF processed from MSW. Using Tables 5 and 6 the following is derived:

$$\frac{19{,}792 \text{ ton RDF} \times 2{,}000 \text{ lb/ton} \times 5{,}610 \text{ Btu/lb}}{11{,}972{,}417 \text{ kwh}} = 18{,}548 \text{ Btu/kwh}$$

Gross production energy

However, the facility required approximately 1.5 x 10^6 kwh of power for in-house use; therefore, the net electricity conversion factor is:

$$\frac{19{,}792 \text{ ton RDF} \times 2{,}000 \text{ lb/ton} \times 5{,}610 \text{ Btu/lb RDF}}{(11{,}972{,}417 - 1{,}516{,}000) \text{ kwh}} = 21{,}938 \text{ Btu/kwh}$$

In this particular case 23,539 ton MSW produced a net amount of electricity equal to 10.46 x 10^6 kwh. If this amount of energy were to have been produced by a conventional steam-electric generation system or by hydroelectric having an average energy conversion factor of 11,100 Btu/kwh, the corresponding energy per ton of MSW would equate to:

$$\frac{10.46 \times 10^6 \text{ kwh (net)}}{23{,}539 \text{ Tons MSW}} \times 11{,}100 \frac{\text{Btu}}{\text{kwh}} = 4.93 \times 10^6 \frac{\text{Btu}}{\text{Ton MSW}}$$

Thus 4.93 x 10^6 Btu per ton of MSW is saved or produced if this production is based upon a conventional power generation system.

The energy to collect the refuse and to deliver it to the power plant is estimated to be 0.23 x 10^6 Btu per ton MSW (see Table 3). The energy to landfill rejects is 0.001 x 10^6 Btu/ton of MSW. The value is derived from the amount of rejects in a ton of MSW, and the value given previously for landfilling, 0.02 x 10^6 Btu/ton. Therefore 0.02 x 10^6 Btu/ton x 7.4 leaves 0.001 x 10^6 to landfill the rejects, a negligible amount. This assumes that the same amount of energy is expended to landfill rejects as to landfill municipal solid waste. Thus, the net energy produced from burning RDF in a power plant is estimated to be 4.70 x 10^6 Btu/ton of MSW.

VI. Conclusions

The estimated energy consumed in recycling using the specified labor-intensive and capital-intensive systems is summarized in Table 7.

TABLE 7

ESTIMATED ENERGY CONSUMED IN RECYCLING
(x10^6 Btu/Ton)

Labor-Intensive Systems	Collection	Processing	Total
Drop-off at recycling center	2.23	0.08	2.31
Drop-off at mobile centers	0.92	0.08	1.00
Separate Curbside	0.23	0.08	0.31
Integrated Curbside	0.23	0.08	0.31
Capital Intensive Systems	0.23	- 4.93	- 4.70*

*Note that there is an energy credit because RDF is burned to produce electricity.

SECTION 2 - GLASS CONTAINERS

I. Introduction

Glass containers make up the largest percentage of glass found in residential/commercial solid waste. Because of this fact, and because scrap glass (cullet) collected in California can be recycled by glass container manufacturers in California, the scope of this study is limited to glass containers, rather than other forms of scrap glass.

A 1976 Solid Waste Management Board Report on Resource Recovery found that glass comprises nine percent by weight of California's residential and commercial solid waste. This estimate is based upon a 1975 generation of 1.8×10^6 tons of glass; an increase to 1.9×10^6 tons is predicted for 1980.[1] In 1973, recycling efforts in California resulted in the collection of 54,000 tons of post-consumer cullet which was used in the production of new glass. Large amounts of in-house cullet are also produced in the manufacturing process and reintroduced into the production of new glass. In-house generated cullet use in glass manufacturing for 1975 was estimated at 270,000 tons.[2] Bottling plants routinely collect and sell broken glass as cullet. Of the 16 California manufacturers surveyed in 1978, nine were using post-consumer generated cullet in the manufacturing process. The amount used ranged from less than one percent to forty percent of the total cullet input. The potential post-consumer cullet use is approximately 1.3 million tons per year, based on a 90 percent use of cullet as a source material for glass container manufacturing. There is presently one front-end operation in California which sorts glass from the waste stream by mechanical means, but its operation has been limited, due to various problems. The majority of post-consumer generated cullet is supplied from recycling centers and imports from other states. California does not export cullet.

There are many uses for cullet generated by both industry and consumer. Besides reuse of waste glass in the manufacture of new glass products, cullet can be used in various other products: foam glass for insulation material and paneling; "slurry seal" for repairing cracks in roadways; glass terrazzo manufactured at lower costs than marble terrazzo, with equal strength and beauty; and waste glass in bricks and pavers. The marketability of these products is being tested. It is potentially economical to use a glass-polymer composite for the production of pipes.[3] This study is limited, however, to the recycling of glass for use in glass container manufacturing. From literature searches and contacts with industry, energy consumption surveys of the use of recycled scrap glass in the glass container manufacturing industry have been conducted. This segment of the report will be limited to the results of these surveys.

II. Methodology

A total of 16 glass container manufacturers throughout California were contacted to identify the type and amounts of raw materials used in container manufacturing, mine locations, manufacturing processes, and modes of transportation used, in order to calculate the amount of energy expended in mining and transporting the raw materials and in manufacturing glass containers. A survey of literature from national studies provided detailed information on glass container manufacture and indicated general patterns of energy usage in mining operations.

The literature identified the components of glass and provided values for energy consumption per ton of material mined. Through discussions with California glass manufacturers, an average mix of raw materials was estimated (see Tables 8a, 8b, 8c). It was determined that, contrary to information in national studies, California manufacturers do not use manufactured soda ash or manufactured lime. Manufactured soda ash is not available because the process does not meet air pollution control standards, natural soda ash

TABLE 8a

REGIONAL VALUES FOR ENERGY EXPENDED IN MINING GLASS COMPONENTS AND MANUFACTURING GLASS CONTAINERS

NORTHERN CALIFORNIA REGION (39.7% STATE PRODUCTION)

Plant #	WEIGHT OF GLASS COMPONENTS FOR 1 TON GLASS								Process Energy[1]
	Silica Sand (lbs)	Feldspathic Sand (lbs)	Limestone (lbs)	Natural Soda Ash (lbs)	Cullet (lbs)	Cullet (%)	Other (lbs)	Batch Weight (lbs)	($x10^6$Btu/Ton Glass)
1	901	191	280	321	564	25	0	2,257	5.23
2	686	527	340	332	382	17	0	2,267	5.11
3	0	1,302	215	262	330	15	94	2,203	5.17
4	1,009	168	280	374	457	20	0	2,288	N/A
5	908	273	273	363	454	20	0	2,271	N/A
AVERAGE	701	492	278	330	437	19	19	2,257	5.17
Energy[2] Factor To Mine	0.722	1.301	0.104	8.2	–				
AVERAGE	0.253	0.320	0.014	1.353	–				1.94
Other MFG Energy[2]									5.54
Total Manufacture and Mining Energy ($x10^6$ Btu/Ton Glass)									12.65

TABLE 8b

REGIONAL VALUES FOR ENERGY EXPENDED IN MINING GLASS COMPONENTS AND MANUFACTURING GLASS CONTAINERS

CENTRAL CALIFORNIA REGION (19.4% STATE PRODUCTION)

Plant #	WEIGHT OF GLASS COMPONENTS FOR 1 TON GLASS								Process Energy[1]
	Silica Sand (lbs)	Feldspathic Sand (lbs)	Limestone (lbs)	Natural Soda Ash (lbs)	Cullet (lbs)	Cullet (%)	Other (lbs)	Batch Weight (lbs)	($x10^6$Btu/Ton Glass)
1	1,346	56	187	280	330	15	0	2,199	Not Available
2	1,062	0	308	342	571	25	0	2,283	7.02
3	901	191	280	320	564	25	0	2,257	5.37
AVERAGE	1,103	82	258	314	488	22	0	2,246	6.19
Energy[2] Factor To Mine	0.722	1.301	0.104	8.2	–				
AVERAGE	0.398	0.052	0.013	1.09	–				1.75
Other MFG Energy[2]									5.54
Total Manufacture and Mining Energy ($x10^6$ Btu/Ton Glass)									13.48

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TABLE 8c

REGIONAL VALUES FOR ENERGY EXPENDED IN MINING GLASS COMPONENTS AND MANUFACTURING GLASS CONTAINERS

SOUTHERN CALIFORNIA REGION (40.9% STATE PRODUCTION)

Plant #	WEIGHT OF GLASS COMPONENTS FOR 1 TON GLASS								Process Energy[1] (x10⁶Btu/Ton Glass)
	Silica Sand (lbs)	Feldspathic Sand (lbs)	Limestone (lbs)	Natural Soda Ash (lbs)	Cullet (lbs)	Cullet (%)	Other (lbs)	Batch Weight (lbs)	
1	1,212	0	325	373	391	17	0	2,301	5,17
2	636	545	272	363	454	20	0	2,270	6.77
3	1,319	0	226	282	333	15	57	2,218	9.95
4	1,319	0	226	282	333	15	57	2,218	N/A
5	1,303	0	223	223	329	15	112	2,190	3.95
6	1,181	0	272	363	454	20	0	2,270	6.57
7	1,181	0	272	363	454	20	0	2,270	6.49
8	1,092	0	280	320	564	25	0	2,257	5.87
9	1,146	246	132	187	428	20	0	2,139	6.64
AVERAGE	1,153	88	248	306	416	19	25	2,235	6.43
Energy[2] Factor To Mine	0.722	1.301	0.104	8.2	—				
AVERAGE	0.416	0.057	.013	1.25	—				1.74
Other MFG Energy[2]									5.54
Total Manufacture and Mining Energy (x10⁶ Btu/Ton Glass)									13.71

[1] From EIS Report, ARB (1972 Data).

[2] From Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing, Phase 4, Battelle Columbus Laboratories, June 1975. Includes manufacturing energy used other than furnace.

is substituted for manufactured soda ash. Although other glass manufacturers use lime and/or limestone, California manufacturers use only limestone. The source of feldspar for California manufacturers is feldspathic sand.

A. Energy in Mining and Manufacturing

The energy values for mining raw materials for glass manufacture in California were derived from a combination of national and regional studies. The following example illustrates the determination of energy values for mining raw materials in glass container manufacture in California. The weights of raw materials according to each plant's specifications were adjusted to represent that which produced one ton of glass. These figures were then multiplied by the energy factor expended in the mining process for that material.[4]

For example: (Northern California)

$$\frac{702 \text{ lbs of silica sand}}{\text{ton of glass}} \times \frac{0.722 \times 10^6 \text{ Btu to mine}}{2000 \text{ lbs/ton}} = 0.2543 \times 10^6 \text{ Btu to mine one ton of glass}$$

Note that the combined weight per ton of major raw materials used in California glass container manufacture when combined with 10 percent cullet is greater than 2000 lbs. The weight of the raw materials put into the furnace is greater than the weight of the glass produced in the furnace because, in addition to process losses, carbon dioxide gas is released, thereby decreasing the weight of the product.

The furnace values for glass manufacturing were derived from information collected by the California State Air Resources Board as part of the Emissions Inventory System survey. Information on fuels such as natural gas were available from this source, but did not include data on electricity. Therefore, to characterize the energy expended by the furnace, including fuel burning and electric boost, we included an additional energy expenditure equivalent to a ten percent electric boost, an average value derived from the statewide survey.

In manufacturing, the value in the category of other "energy expenditures" was derived directly from a report done by Battelle Columbus Laboratories. The value is the sum of batch handling, cullet crushing, fining and conditioning, forming, post-forming, product handling, and space heating.[5] The in-house cullet levels, as a percentage of total batch weight, were provided by the manufacturers surveyed. The statewide average energy expended in the entire process using raw materials and in-house cullet was derived by averaging the weighted values for each of the three California regions. Each region was weighted by the total capacity estimated from the furnace capacities of the manufacturing facilities in the region.

B. Energy in Material Transport

The following methodology was used in estimating the energy expended in the transportation of raw materials from mine locations to glass container manufacturing plants. By contacting various California glass container manufacturers, mine sites were located and the distance calculated to plant location. If the material was transported by rail, the distances were calculated using a Southern Pacific Railroad map. If the material was transported by truck, a California road map was used to calculate the distance. The energy value of 720 btu/ton mile for rail and 2400 Btu/ton mile for truck were used for the calculations. The origin of these values is described in Section 1 of this chapter.

Rail Transport

$$\frac{500 \text{ miles} \times 300 \text{ lbs of material/ton of glass}}{2000 \text{ lbs/ton}} \times 720 \text{ Btu/ton mile}$$

$$= 54{,}000 \text{ Btu/ton of glass}$$

Truck Transport

$$\frac{65 \text{ miles} \times 200 \text{ lbs of material/ton of glass}}{2000 \text{ lbs/ton}} \times 2400 \text{ Btu/ton mile}$$

$$= 15{,}600 \text{ Btu/ton of glass}$$

III. Glass Container Manufacture Using Virgin Materials

The energy values derived for 16 glass container manufacturers in California were summarized into Northern, Central, and Southern California average values. The division into three marketing areas, essentially the San Francisco Bay Area, the Central Valley Area, and the Los Angeles Area provides a framework for consideration of recycling opportunities later in the study. Figures 2, 3, and 4 indicate the locations of the glass container manufacturers and their sources of raw materials. Tables 8a, 8b, and 8c, show the regional values for the energy expended in mining glass components

FIGURE 2

The Northern California Glass Container Manufacturers & Their Sources of Raw Materials

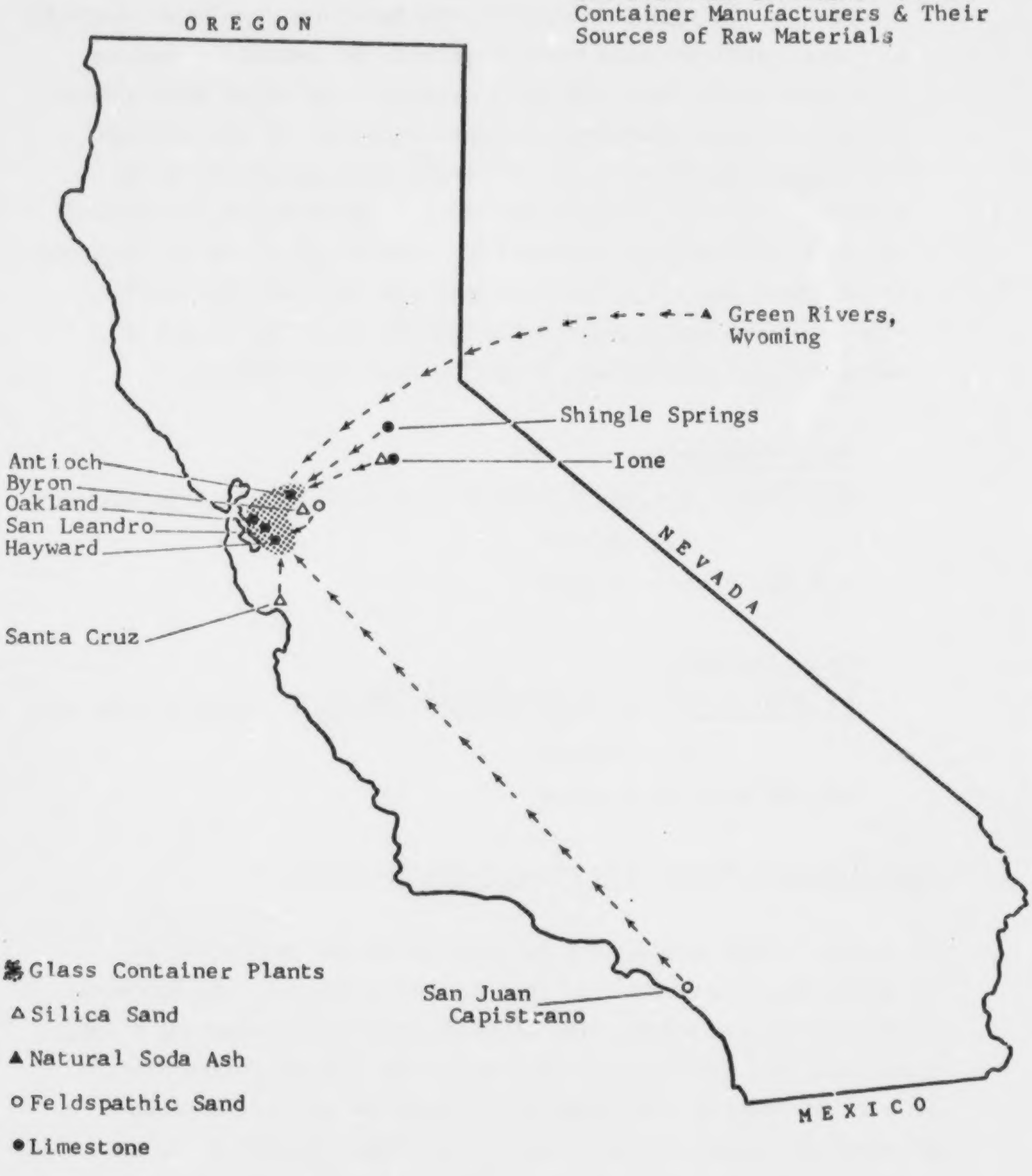

O R E G O N
Green Rivers, Wyoming
Shingle Springs
Ione
Antioch
Byron
Oakland
San Leandro
Hayward
Santa Cruz
N E V A D A
San Juan Capistrano
M E X I C O
▨ Glass Container Plants
△ Silica Sand
▲ Natural Soda Ash
○ Feldspathic Sand
● Limestone

FIGURE 3

The Southern California Glass Container Manufacturers & Their Sources of Raw Materials

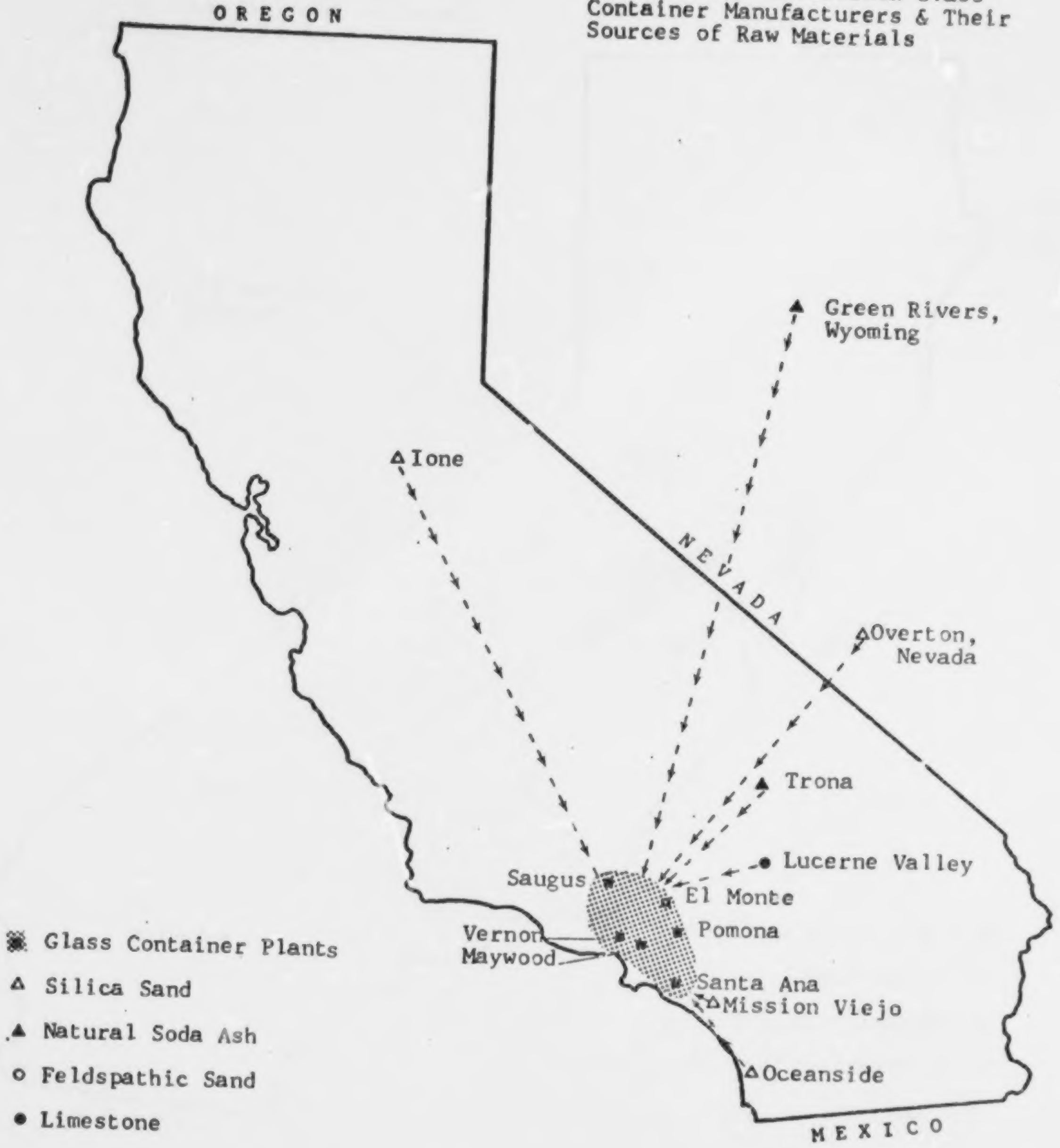
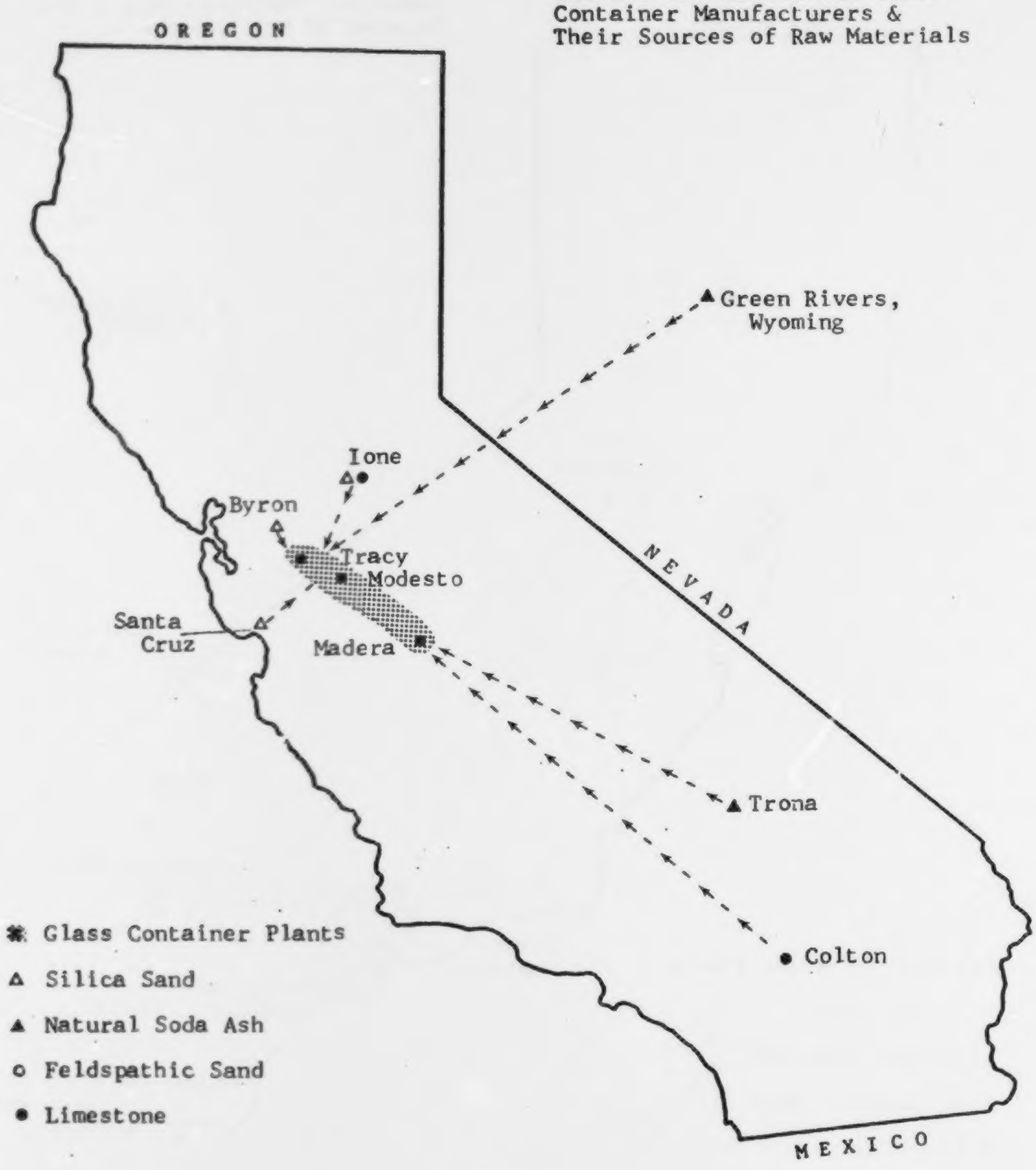

OREGON
NEVADA
MEXICO
Green Rivers, Wyoming
Ione
Overton, Nevada
Trona
Lucerne Valley
Saugus
El Monte
Pomona
Vernon
Maywood
Santa Ana
Mission Viejo
Oceanside
▩ Glass Container Plants
△ Silica Sand
▲ Natural Soda Ash
○ Feldspathic Sand
● Limestone

FIGURE 4

The Central California Glass Container Manufacturers & Their Sources of Raw Materials


OREGON
Green Rivers, Wyoming
Ione
Byron
Tracy
Modesto
Santa Cruz
Madera
NEVADA
Trona
Colton
MEXICO
✱ Glass Container Plants
△ Silica Sand
▲ Natural Soda Ash
○ Feldspathic Sand
● Limestone

and manufacturing glass containers. Tables 9a, 9b, and 9c show the regional values for energy expended to transport raw materials to glass manufacturers.

TABLE 9a

REGIONAL VALUES FOR ENERGY EXPENDED TO TRANSPORT RAW MATERIALS TO GLASS MANUFACTURERS

NORTHERN CALIFORNIA REGION

Plant #	Raw Material Transport Energy Expenditure Values (BTUs/Amount of Material for One Ton of Glass)							
	Silica Sand		Feldspathic Sand		Soda Ash		Limestone	
	Rail	Truck	Rail	Truck	Rail	Truck	Rail	Truck
1	41,130			99,790	110,890		12,790	
2		53,470		9,490	107,070			36,720
3	0	0		54,680	92,160			33,610
4	51,170			23,210	131,320		16,250	
5	44,180			23,770	94,300		18,960	
Range:								
Low	41,130	NA		9,490	94,300		12,790	33,610
High	51,170	53,470		99,790	131,320		18,960	36,720
AVERAGE	47,490 (Total/Four)			42,190	107,150		23,670 (Total/Five)	
Total Transport	220,400 BTU /Ton of Glass							

TABLE 9b

REGIONAL VALUES FOR ENERGY EXPENDED TO TRANSPORT RAW MATERIALS TO GLASS MANUFACTURERS

CENTRAL CALIFORNIA REGION

Plant #	Raw Material Transport Energy Expenditure Values (BTUs/Amount of Material for One Ton of Glass)							
	Silica Sand		Feldspathic Sand		Soda Ash		Limestone	
	Rail	Truck	Rail	Truck	Rail	Truck	Rail	Truck
1		96,920		70,670		104,310		134,570
2		139,330	0	0	106,030		33,290	
3	22,200			85,800	101,710		6,900	
Range:								
Low	NA	96,920		70,670	101,710	NA	6,900	NA
High	NA	139,330		85,800	106,030	NA	33,290	NA
AVERAGE	86,150 (Total/Three)			78,230	104,020 (Total/Three)		58,250 (Total/Three)	
Total Transport	326,650 BTU /Ton of Glass							

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TABLE 9c

REGIONAL VALUES FOR ENERGY EXPENDED TO TRANSPORT RAW MATERIALS TO GLASS MANUFACTURERS

SOUTHERN CALIFORNIA REGION

Plant #	Raw Material Transport Energy Expenditure Values (BTUs/Amount of Material for One Ton of Glass)							
	Silica Sand		Feldspathic Sand		Soda Ash		Limestone	
	Rail	Truck	Rail	Truck	Rail	Truck	Rail	Truck
1	197,520	101,810	0	0	174,150			35,090
	149,660							
2	69,120			58,880	171,820			8,180
3		94,990	0	0	130,810			21,710
4	184,160	24,080	0	0	13,760		10,120	
	104,120							
5		85,050	0	0	93,280		6,910	22,900
							14,910	
6		85,050	0	0	18,430		5,930	19,630
							12,780	
7	78,660		0	0	16,260		7,110	
8	165,940		0	19,150	81,170	33,720		16,270
					57,450			
Range: Low	69,120	24,080	NA	19,150	13,760	NA	5,930	8,180
High	197,520	101,810	NA	58,880	174,150	NA	10,120	35,090
AVERAGE	104,070 (Total/Eight)		39,020 (Total/Two)		84,500 (Total/Eight)		15,770 (Total/Eight)	
Total Transport	243,360 BTU /Ton of Glass							

IV. Glass Container Manufacture Using Post-Consumer Cullet

A. Cullet in Manufacture

The glass manufacturing industry is actively seeking to increase the input level of post-consumer cullet from the current 15 to 20 percent average nationwide to around 30 to 35 percent.[6] By 1980, it is anticipated that 30 percent of potentially available post-consumer cullet will be bought by the glass manufacturers to provide 40 to 50 percent of the source material for new glass container production. Current levels of cullet use are not restricted by a lack of technology in producing a quality container; rather it has been demonstrated that, barring slight degrading of microstructural integrity, 100 percent cullet can be used, with 90 percent being an optimum to produce a good quality glass container.[8] Cullet availability appears to be a limiting factor; there currently is not enough quality cullet supplied on a continual basis from post-consumer recycling efforts to support manufacturing at high cullet levels.

B. Cullet Quality

Glass manufacturers prefer to use in-house generated cullet to post-consumer cullet because the color composition of in-house cullet is known, whereas that of post-consumer cullet may not be homogenous. Also, the known purity of in-house cullet being free of aluminum tops, plastic, and other glass container packaging peripherals, draws preference over the post-consumer cullet. The demand for flint (clear) cullet is greatest because most glass containers are clear. Mixed cullet cannot be used in flint glass container production. Green and/or amber cullet can be used in the production of green bottles in that mixed cullet does not significantly degrade the acceptability of green glass.

The use of cullet has several energy saving benefits. Cullet assists in the melting process by providing a good base for heat transfer in the molten bath; thus, the batch can liquify at a lower temperature. With a consistently reduced heat, the life of the furnace is extended and time is saved by a faster "melt". To illustrate the industrial value of cullet, when there exists a scarcity of cullet on the market, manufacturers will intentionally produce it.[9] An east coast plant reports that, with the use of higher cullet levels, the plant is able to circumvent the addition of air pollution control equipment. Local air quality standards are met without the use of scrubbers and the opacity of stack emissions is reduced.

C. Energy Savings with Cullet Use

The fact is generally acknowledged in the glass manufacturing industry that there is an energy savings accrued with the increased use of cullet, whether in-house or post-consumed generated. The degree to which this energy savings benefits industry and the consumer is debatable because of the lack of information available on energy consumption using large cullet levels for source material. Inasmuch as the manufacturing process accounts for the majority of the total energy for the one-way bottle system, any reduction of energy consumption in this stage would be significant in the entire system.[10]

Various studies have been made to ascertain the amount of energy savings associated with a certain level of cullet. A 1976 study by Battelle Columbus Laboratories reports that addition of 35 percent cullet results in a 3 to 5 percent savings in melting energy. Further, at 60 percent cullet levels, a 13 percent to 35 percent energy savings is realized. Battelle has projected an overall energy savings in 1980 with the use of 35 percent cullet at 2.3 percent for the entire glass container system. The savings on site to a glass manufacturing industry would amount to 3.5 percent.[11] A study by Gordian Associates, 1974, reports that increased use of cullet would result in little impact on energy consumption of glass manufacturers. Gordian reports that an increase of 20 to 50 percent produces a 6.8 percent decrease in the energy required for melt. The overall energy savings for the industry in the complete manufacturing process is approximately three percent.[12] Hsu, 1971, reports that for every percent increase in cullet, 1/4 to 1/3 percent energy savings is realized.[13] A Swiss company has found that at 50 percent cullet levels, 13 percent fuel savings is realized.[14] (See Table 10.)

At present there is only one American company which consistently uses 50 to 60 percent cullet levels in the production of glass containers. They have found that higher levels of cullet would be preferred, approaching 90 percent, but that the availability of a constant supply of post-consumer cullet is the limiting factor. They maintain that the quality of the container is not diminished by the increased levels; tests at the plant have shown that up to the 90 percent level, there is no appreciable quality loss. Taking all variables into consideration, the plant has realized an overall 15 percent fuel use reduction in furnace operation.

TABLE 10

ENERGY SAVINGS WITH INCREASED CULLET LEVELS

Study	Cullet level	Energy Savings in furnace	Standardized Savings 1 ton product x 10^6 Btu
Battelle	to 35%	3-5%	.2 to .3
	35-60%	13-25%	.8 to 2.1
Gordian	20-50%	6.8%	.4
Hsu	1% increase	1/4 to 1/3%	.7 to 1.0 @ 50%
Glass Con. Corp.	50-60%	15%	.9
Gloor	50%	13%	.8

V. Conclusions

Table 11 summarizes the energy values for glass furnace, and for ancillary operations in glass container manufacture. The total amount of energy expended to produce one ton of glass containers in California from virgin materials including mining, transport, and manufacture is estimated at 13.5 x 10^6 Btu/ton. The total found in a national study is 16.2 x 10^6 Btu/ton. These estimates also appear in Table 11.

TABLE 11
AVERAGE ENERGY VALUES FOR GLASS CONTAINER MANUFACTURING IN CALIFORNIA WITHOUT USING POST-CONSUMER CULLET

STEP IN PROCESS	Regional Average Btu x 10^6/ton Glass NORTH	CENTRAL	SOUTH	Statewide Average Btu x 10^6/ton Glass	National * Report Average Btu x 10^6/ton Glass
Raw Material	1.94	1.75	1.74	1.82	2.170
Transport to Manufacture	0.22	0.33	0.24	0.25	0.385
MANUFACTURE					
Furnace	5.17	6.19	6.43	5.88	8.135
Other **	5.54	5.54	5.54	5.54	5.544
TOTAL	12.87	13.81	13.95	13.49	16.2
1978	North	Central	South	Statewide Average	National Report Ave.
Cullet Level (% of Total Batch)	19%	22%	19%	20%	10%

*From Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing, Phase 4 - Energy Data and Flowcharts - High Priority Commodities, Battelle Columbus Laboratories, for the Bureau of Mines, 27 June 1975.

**Indicates other energy used at the glass manufacturing plant including batch handling, cullet crushing, fining and conditioning, forming, post-forming, product handling, and space heating.

Assuming that 5.88 x 10^6 Btu are expended in the furnace to produce one ton of glass, by using 50 to 60 percent cullet per batch, a 15% energy savings is accrued in the melting process alone, representing a savings of approximately 0.9 x 10^6 Btu/ton. An additional energy savings of 0.3 x 10^6 Btu is realized in the mining and transport of virgin material to the plant when 50 to 60 percent cullet is used. Collection costs of recycling scrap glass from either a high technology front end system and/or a recycling center plus transportation costs must be added to the energy required in production of one ton of glass.

The energy used to transport empty bottles to the bottling facility is not considered, nor are the ancillary process energies such as: crown manufacturing, bottle washing and filling, etc. The total energy value using 50% cullet is 12.33 x 10^6 Btu/ton container; an energy savings of 8.6%. Please see Table 12 for the component breakdown.

TABLE 12

GLASS CONTAINER PRODUCTION ENERGY

AT DIFFERENT CULLET INPUT LEVELS

% Cullet	Process	Energy Required (Btu x 10^6/Ton Glass)
100	Collection[1]	0.31
	Transport to Mfg[2]	0.34
	Furnace	5.00
	Other	5.54
	Total	11.19
50	Production	5.58[3]
	Mining & Transport	1.04
	Furnace	2.94
	Other	2.77
	Total	12.33
20	Total	13.49[4]

Notes:

[1] Collection: assume separate curbside collection system.

[2] Transport to Mfg found from weighted average number of miles recycling centers have glass cullet transported to manufacturing plant. Average 143 one-way miles 2400 Btu/Ton-mile yields 0.34 x 10^6 Btu/Ton glass for California. Source of information is SB 650 grant proposals.

[3] Figure obtained from: 11.19 x 0.50 = 5.58.

[4] Reflects current input levels. (See Table 11).

REFERENCES - SECTION 2

1. California State Solid Waste Management Board, State Solid Waste Management Board, Resource Recovery Program, Volume II, Unabridged Report, June 1976, Pages III-5,6.

2. Ibid, Pages C-64, 65.

3. Ibid.

4. Battelle Columbus Laboratories, Energy Use Patterns in Metallurgical and Non-Metallic Mineral Processing, June 1975, Page 4.

5. Ibid.

6. Gordian Associates, Inc., The Potential for Energy Conservation in Nine Selected Industries, The Data Base, Volume 7, Glass, New York, 1974, FEA D/74 186.

7. Environmental Protection Agency, The Beverage Container Program, EPA/R2/72-059, 1972.

8. Private discussions with Picket Scott, Glass Container Corporation, September 1978.

9. Environmental Protection Agency, op. cit.

10. Robert G. Hunt, et. al., Resource and Environmental Profile Analysis of Nine Beverage Container Alternatives, Final Report, EPA, 1974, Page 49.

11. Battelle Columbus Laboratories, Energy Efficiency Improvement Target for SIC 32: Stone, Clay, and Glass Products, Ohio, June 1976, FEA D-77/248.

12. Gordian Associates, op. cit.

13. J.P. Hsu, "Heat Balance and Analysis of Fuel Consumption in Grunching, Connecticut," Glass Industry, February 1971, Page 61.

14. Gloor Recycling, Inc., Information on the Recycling of Scrap Glass, Dagmersellen, Switzerland, 1976.

SECTION 3 - ALUMINUM CONTAINERS

I. Introduction

In 1976, 160,000 tons of aluminum cans were consumed by Californians. Of this amount 45 percent or approximately 71,500 tons were recovered and the remainder was landfilled.[1,2] This portion of the report will compare the energy consumed when using recycled aluminum cans in place of virgin materials in the aluminum can production process.

With proper alloying and removal of impurities, recycled aluminum derived from can scrap can replace aluminum derived from virgin sources. Because of this fact 90 percent of all aluminum cans that are recycled are transported to primary smelters located out-of-state to be remelted and introduced into the aluminum smelting process.[3]

However, there is a problem in producing aluminum from scrap; it generally does not have the same degree of purity as aluminum produced entirely from virgin materials because of the contamination that occurs during the collection, storage, and transport of the can scrap. As contamination levels increase so does the energy consumption rate that is required to flux the scrap. It is therefore desireable, in terms of energy conservation and economics, to utilize scrap that requires as little alloying and fluxing as possible.

In view of this, a logical end use for can scrap would be back into cans except that the aluminum industry expressed concern that the high magnesium can end (containing a content of 4.0 to 5.0 percent) would make the melted can off-spec for body stock, the major potential end use. It was found, however, that magnesium losses occuring during normal smelting are sufficient to bring the final can scrap product very near can body stock specifications.[4]

II. Methodology

The methodology used to achieve the objective of comparing the energy requirements of the two processes consisted of obtaining energy requirement figures for resource extraction (material inputs), transportation of the raw and intermediate materials, and materials processing. This information was obtained through literature search and contacts with the aluminum industry.

Much of the information contained in this section was derived from the following reports:

- Energy Use Patterns for Metal Recycling, by the U.S. Government Interior, Bureau of Mines.

- The Potential for Energy Conservation in Nine Selected Industries, Volume 5, Aluminum, by Gordian Associates, Inc.

- Energy Use Patterns in Mettalurgical and Nonmetallic Mineral Processing, Phase 4 - Energy Data and Flowcharts -- High Priority Commodities by Battelle Columbus Laboratories.

- Environmental Considerations of Selected Energy Conserving Manufacturing Process, Volume VIII, by Arthur D. Little, Inc.

The latter three reports supplied the bulk of the information used in determining the energy requirements of producing aluminum from virgin sources, while the first report supplied the basis for determining the energy requirements when using recycled/scrap aluminum in the production process.

Existing information regarding primary production of aluminum is adequate to supply an overall approximation of the energy requirements associated with each step of the production process. However, there is a general lack of information specifically dealing with the energy requirements associated with using recycled/scrap aluminum in the production process. Because of this, it was felt that contact with the aluminum industry was necessary. This contact was achieved via correspondence and telephone conversation specifically regarding the use of recycled aluminum containers in the production process and the effect this would have on overall energy consumption.

Where possible, transportation figures have been included in the energy consumption estimations. We assumed that these transportation figures, taken from reports, are accurate and are representative of California as well as the remaining states in the U.S. This is because there are a limited number of primary aluminum smelters serving the nation.

III. Primary Production of Aluminum Ingot Using Virgin Materials

The production of aluminum takes place in two steps which are discussed in Sections B1 and B2 following: (1) the processing of bauxite ore into alumina using the Bayer process, (2) the reduction of alumina into aluminum ingot using the Hall-Heroult process. These two operations may be conducted at entirely separate locations; however, the aluminum industry generally tries to take advantage of the economics of placing alumina production and aluminum reduction facilities at the same location.

A. Resource Extraction and Transport

Besides the main ingredient of bauxite ore, there are two other raw material inputs required for the Bayer process -- rock salt and limestone, which are converted into caustic soda and lime, respectively. Complementary operations of the Hall-Heroult process such as anode manufacture require processed petroleum coke and pitch binder. In addition, the Hall-Heroult process involves small amounts of cryolite, aluminum fluoride and fluorspar in the electrolytic bath.

1. Bauxite Mining

At the present time, bauxite ore is the only commercially exploited source of aluminum. Although the United States is the World's largest consumer of bauxite, approximately 90 percent of the bauxite used here is supplied by foreign countries such as Jamaica, South America, and Australia. Domestic sources, the largest of which is located in Arkansas, supply only 10 percent of our needs. In addition, it appears that imports of bauxite will increase unless alternative domestic supplies are located.[5]

Most bauxite ore is mined by open-pit methods. On-site processing of bauxite includes milling and crushing, classifying, washing, and kiln drying to remove excess moisture. After this processing the bauxite is transported to the United States, although sometimes it is processed into alumina prior to being transported.

In 1976, almost all of the bauxite and 42 percent of the alumina used in the United States was imported.[6] These imports reduce the amount of energy used in the United States to produce aluminum. However, even though these energy expenditures occur overseas, this study will include them in the estimate of energy required to produce one ton of aluminum.

It is estimated that approximately 2.41×10^6 Btu are expended mining and processing bauxite to produce one net ton of aluminum.[7] Figures taken from the Battelle Columbus Laboratory report indicate that an additional 2.38×10^6 Btu are required to transport the bauxite to the alumina production site.[8]

2. Rock Salt Mining

The processing of bauxite into alumina employs strong caustic soda solutions. The major raw material for these solutions is salt which is combined with lime. It is assumed that salt is obtained from rock salt mines which are widely distributed throughout the United States.[9] After mining, the rock salt is dissolved to make a brine solution which is then electrolyzed to produce the caustic soda used in the digestion portion of the Bayer process.

It is estimated that approximately 0.01×10^6 Btu are expended mining rock salt used to produce enough caustic soda for one net ton of aluminum.[5]

3. Limestone Mining

Most limestone is mined in surface quarries, with underground mining accounting for only 4 percent of the total crushed stone. Following blasting from the rock face, the broken stone is crushed and screened.[10] The limestone is then processed into lime.

It was estimated that approximately 1.05×10^6 Btu was expended mining and processing limestone into lime to produce one net ton of aluminum.[8] This figure reflects surface mining, not underground mining.

4. Petroleum Coke

The single largest use for petroleum coke is in the aluminum production process. The coke is calcined to be used in the anodes and furnace lining of the reduction "pots" of the Hall-Heroult process.

It was estimated that approximately 26.81×10^6 Btu are expended processing and calcining the coke used in producing one net ton of aluminum.[5]

5. Cryolite

This material is rare to the extent that it occurs in useable quantities at only one place in the world, at Ivigtut in southwestern Greenland.[11] Therefore, the aluminum industry uses synthetic cryolite which is manufactured in the United States. The made-up cyrolite is then supplemented with aluminum fluoride in the electrolytic bath.

It was estimated that 5.45 x 10^6 Btu are expended in the production and transport of enough synthetic cryolite to produce one net ton of aluminum.[8]

6. Aluminum Fluoride

This material is produced by combining fluorspar and sulphur and is used in conjunction with synthetic cryolite in the electrolytic bath of the reduction process.

It was estimated that 1.02 x 10^6 Btu are expended to produce enough aluminum fluoride for one net ton of aluminum.[8]

7. Fluorspar

This material is used in conjunction with synthetic cryolite in the electrolytic bath.

It was estimated that approximately 0.01 x 10^6 Btu are expended mining, processing, and transporting enough fluorspar to produce one net ton of aluminum.[8]

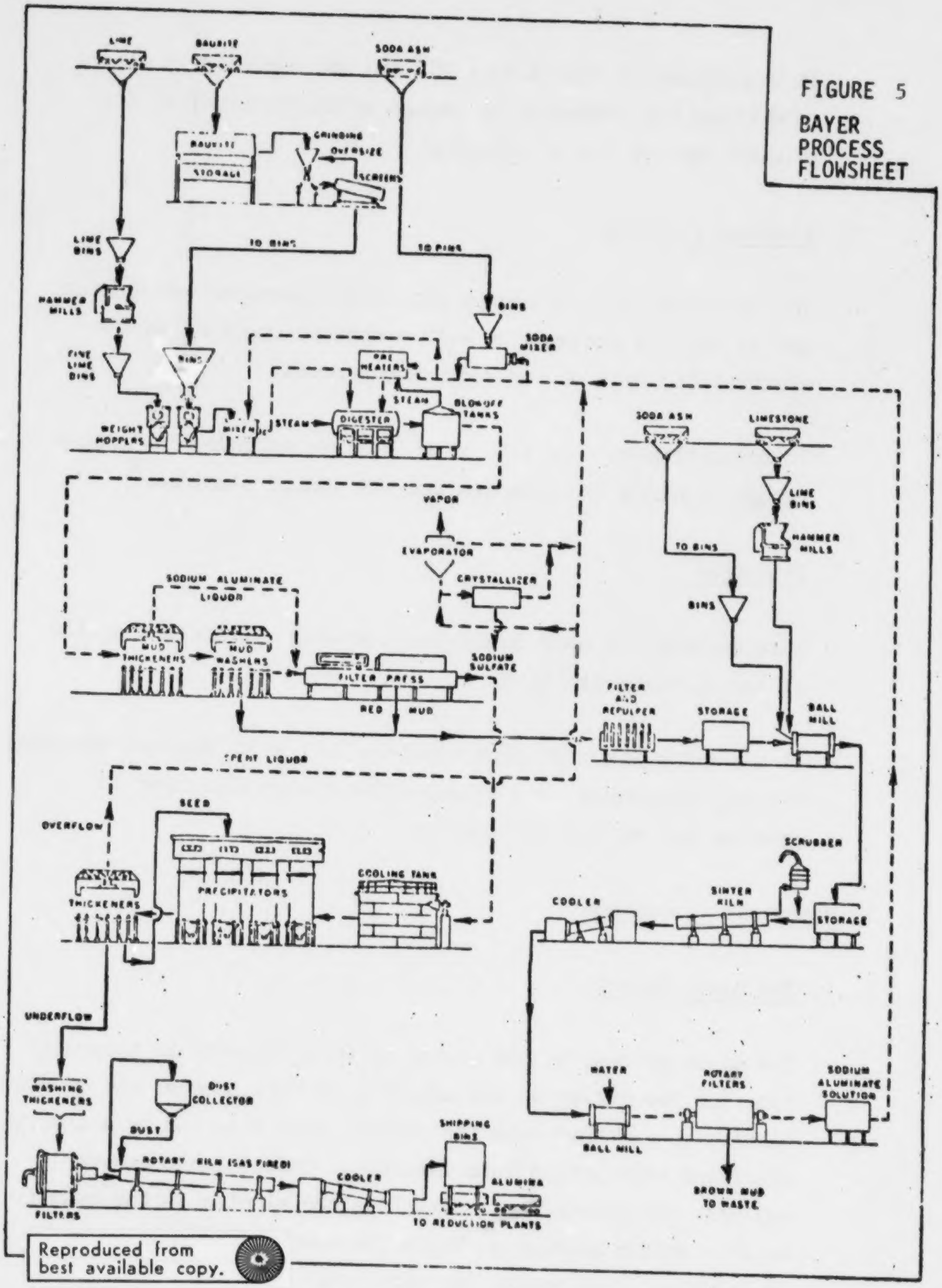
B. Materials Processing

1. The Bayer Process

The Bayer process is the method by which alumina is separated from the impurities in the bauxite. In this process the crushed bauxite is combined with the caustic soda solution by a slurry mixer and then pumped into digestors. Under high pressure and heat the caustic soda dissolves the alumina in the bauxite to form sodium aluminate. While the sodium aluminate remains in solution, iron oxides and other solid impurities drop to the bottom of the settling tank where they are filtered out as "red mud" and pumped to a disposal pond. The remaining solution is cooled and seeded with the aluminum hydroxide

FIGURE 5

BAYER PROCESS FLOWSHEET


LIME
BAUXITE
SODA ASH
BAUXITE
STORAGE
GRINDING
OVERSIZE
SCREENS
LIME BINS
HAMMER MILLS
TO BINS
TO BINS
BINS
SODA MIXER
FINE LIME BINS
BINS
PRE HEATERS
STEAM
BLOWOFF TANKS
WEIGHT HOPPERS
MIXER
STEAM
DIGESTER
VAPOR
EVAPORATOR
CRYSTALLIZER
SODIUM ALUMINATE LIQUOR
MUD THICKENERS
MUD WASHERS
FILTER PRESS
SODIUM SULFATE
RED MUD
SPENT LIQUOR
SEED
OVERFLOW
THICKENERS
PRECIPITATORS
COOLING TANK
UNDERFLOW
WASHING THICKENERS
DUST COLLECTOR
DUST
ROTARY KILN (GAS FIRED)
COOLER
SHIPPING BINS
ALUMINA
FILTERS
TO REDUCTION PLANTS
SODA ASH
LIMESTONE
LIME BINS
HAMMER MILLS
TO BINS
BINS
FILTER AND REPULPER
STORAGE
BALL MILL
SCRUBBER
COOLER
SINTER KILN
STORAGE
WATER
ROTARY FILTERS
SODIUM ALUMINATE SOLUTION
BALL MILL
BROWN MUD TO WASTE

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SOURCE: Pre-Investment Data for the Aluminum Industry, Studies in Economics of Industry No. 2 (New York: United Nations, 1966).

crystals, then circulated through a series of precipitators producing alumina trihydrate which is then filtered, washed, and roasted at 1800° F in a calcining kiln to remove chemically attached water. A fine white powder, commercially pure alumina, remains for transport to a smelter. See Figure 5 for a complete illustration of the Bayer process.

Presently there are 9 alumina plants in the United States; 6 on the Gulf Coast, 2 in Arkansas, and 1 in the Virgin Islands which together produced approximately 7,700,000 short tons in 1975.[12] See Figure 6 for all United States production locations.

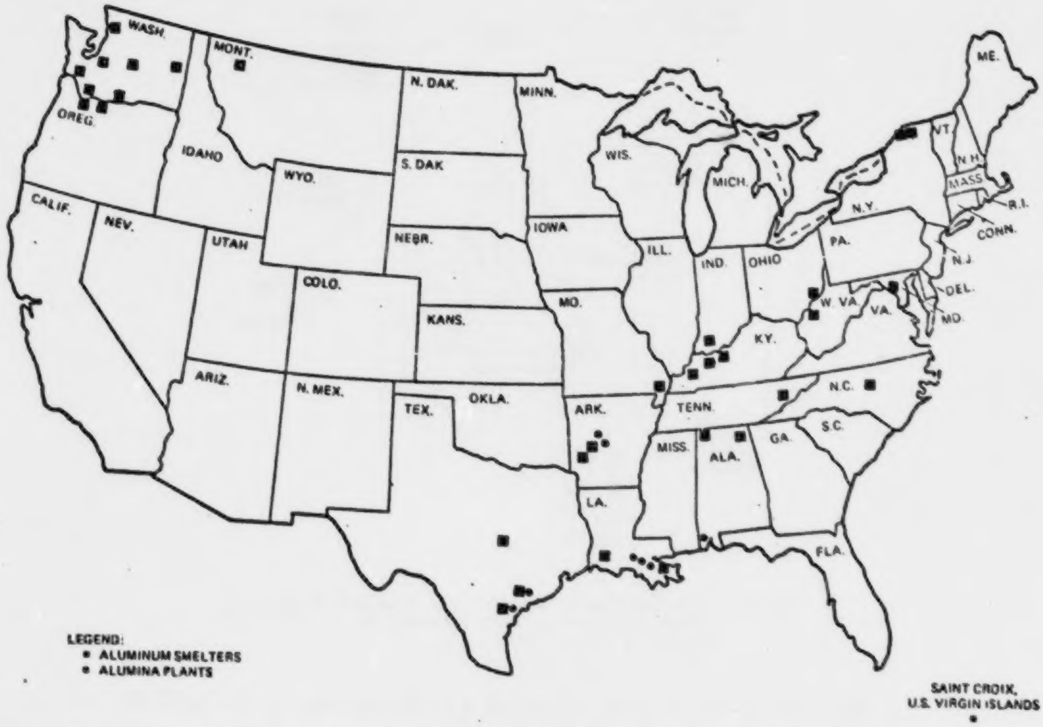
WASH.
MONT.
N. DAK.
MINN.
ME.
OREG.
IDAHO
WYO.
S. DAK
WIS.
MICH.
VT.
N.H.
MASS.
R.I.
CONN.
N.Y.
CALIF.
NEV.
UTAH
NEBR.
IOWA
ILL.
IND.
OHIO
PA.
N.J.
DEL.
MD.
COLO.
KANS.
MO.
W. VA.
VA.
KY.
ARIZ.
N. MEX.
TEX.
OKLA.
ARK.
TENN.
N.C.
S.C.
MISS.
ALA.
GA.
LA.
FLA.
LEGEND:
■ ALUMINUM SMELTERS
● ALUMINA PLANTS
SAINT CROIX,
U.S. VIRGIN ISLANDS

Figure 6. Location of Alumina Plants and Aluminum Smelters in the United States

SOURCE: Environmental Considerations of Selected Energy Conserving Manufacturing Process ... Volume VIII ... Arthur D. Little, Inc., Cambridge, Mass. EPA/600/7-76/034H, Dec. 1976

It was estimated that approximately 37.25×10^6 Btu are expended during the Bayer process to make enough alumina to produce one net ton of aluminum. This figure does not include the energy expended during the mining of the mineral inputs nor does it include the transportation costs associated with transporting the bauxite and other minerals to the alumina smelting operation.

2. The Hall-Heroult Process

This process involves the reduction of the alumina crystals into pure aluminum ingot, which can then be manufactured into the final product.

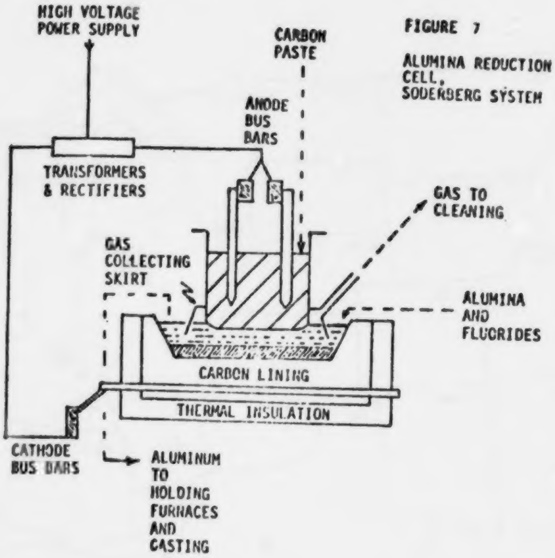

FIGURE 7

ALUMINA REDUCTION CELL, SODERBERG SYSTEM

HIGH VOLTAGE POWER SUPPLY
CARBON PASTE
ANODE BUS BARS
TRANSFORMERS & RECTIFIERS
GAS TO CLEANING
GAS COLLECTING SKIRT
ALUMINA AND FLUORIDES
CARBON LINING
THERMAL INSULATION
CATHODE BUS BARS
ALUMINUM TO HOLDING FURNACES AND CASTING

SOURCE: Pre-Investment Data for the Aluminum Industry; Studies in Economic of Industry No. 2 (New York: United Nations, 1966)

In this process the alumina crystals are dissolved in an electrolytic reduction cell or "pot" which contains a molten cyrolite bath. The bottom of this pot is lined with carbon and from its top are carbon anodes which are suspended in the bath (see Figure 7 for illustration of alumina reduction cell). When direct current passes through the suspended anodes, the cryolite bath acts as an electrolyte and breaks the alumina down into its components -- aluminum and oxygen. The carbon lining acts as a cathode which attracts the molten aluminum to the bottom of the pot. As the pure molten aluminum builds up in depth it is siphoned off and carried by crucible to a furance where it is mixed with alloys and then finally cast into various shapes and weights of ingots.

Because electricity is a significant part of the total production cost of aluminum, aluminum producers have historically located where their power costs are low, mainly along rivers where they can take advantage of hydropower. There are 31 aluminum smelters (owned by 12 companies) in the United States located along the Mississippi and Ohio Rivers, in Massena, New York, Washington, Oregon and Western Montana.[12] (See Figure 6.)

Approximately 54 percent of the total energy consumed to make one net ton of aluminum is spent on the smelting of alumina to aluminum.[5] It was estimated that approximately 168.00×10^6 Btu are expended during the Hall-Heroult process to produce one net ton of aluminum. This figure includes only energy used in the smelting process and does not include any pollution control energy expenditures.

C. Summary of Energy Consumption

As shown in Tables 13 and 14, the largest use of energy (54 percent), is involved in the Hall-Heroult Process. The next largest usage occurs in the casting to can manufacture process. Table 15 shows the percentages of the various types of primary energy used throughout the primary production process.

TABLE 13

OVERALL INPUT OF MATERIALS
(To Produce 1 Net Ton of Aluminum Can)

Material Input	Energy Expended (1) ($x10^{6}$ BTU)	Amount (In Tons)
Bauxite Mining	0.29^{B}	4.0^{L}
Bauxite Processing	2.12^{B}	
Transport of Bauxite to Alumina Producer	2.38^{B}	
Rock Sale Mining	0.01^{G}	0.007^{L}
Limestone Mining	0.02^{B}	
Lime Production	0.03^{B}	0.113^{L}
Caustic Soda Production	1.75^{G}	0.063
Natural Soda Ash Production	0.03^{G}	0.075^{L}
Petroleum Coke Production	0.06^{G}	0.55^{L}
Coke Calcining	26.75^{G}	
Pitch Production	5.67^{G}	0.15^{L}
Cryolite Make-up & Transport	5.45^{B}	0.35^{L}
Aluminum Fluoride Production	1.02^{B}	0.02^{L}
Fluorspar Mining & Transport	0.01^{B}	0.003^{B}
Anthracite Mining & Transport	0.59^{B}	0.02^{B}
Anthracite Calcining	0.50^{B}	
TOTAL MATERIAL INPUT	46.68	5.036
Ingot Manufacture Process		
Bayer Process	37.25^{B}	
Hall-Heroult Process(2)	168.00^{B}	
TOTAL INGOT MANUFACTURING	205.25	
Can Manufacturing Process		
Casting, Rolling, Can Manufacture (3)	61.63^{A}	

TOTAL ENERGY REQUIRED
Using virgin materials 313.56 x 10^{6} Btu/ton can product.

Notes:

1) In Btu's per ton of finished can product.

2) Figure does not include pollution control energy expenditures which may be assumed negligible.

3) Casting to can manufacture includes internal transportation energy and landfill residue energy (7% x 0.23 x 10^{6} Btu/ton).

Sources:

B - Battelle Columbus Laboratories, Energy Use Pattern in Metallurgical & Non-metallic Mineral Processing, Phase 4, June 1975.

L - Arthur D. Little, Inc., Environmental Considerations of Selected Energy Conserving Manufacturing Process, Vol. VIII, Dec. 1976.

G - Gordian Associates, Inc., The Potential for Energy Conservation in Nine Selected Industries, the Data Base, Vol. 5 Aluminum 1974.

A - Aluminum Associate Energy Content in Aluminum Cans Historial Performance and Future Potential (#2) September 15, 1976.

TABLE 14

THE DISTRIBUTION OF FUELS BY PROCESSING STEP

Smelting of Alumina to Aluminum	53.5%
Casting to Can Manufacturing	19.7%
Refining imported Bauxite to Alumina (Bayer Process)	11.9%
Coke Calcining	8.5%
Production of Pitch	1.8%
Caustic Soda Production	0.6%
Aluminum Floride Production	0.3%
Misc. Other Steps including mining and transport	3.7%

TABLE 15

PRIMARY ENERGY USE BY TYPE OF RESOURCE

Coal	0.5%
Oil Products	15.1%
Natural Gas	9.0%
Derivative Fuels*	3.2%
Purchased Electricity**	72.2%

* Consumed mainly in the pitch manufacture stage.

** The primary fuel for electricity generation would have been greater but for the fact that 50% of the electric energy was derived from hydro-electric stations.

SOURCE: The Potential for Energy Conservation in Nine Selected Industries. The Data Base. Volume 5, Aluminum. Gordian Associates, Inc., New York

IV. Secondary Production of Aluminum Using Recycled Cans

A. Scrap Transport

Most aluminum cans in California are recovered from the waste stream through local recycling centers. These recycling centers, found throughout the State, in turn sell the scrap cans to the three major aluminum production companies, namely Kaiser, Reynolds, and Alcoa. Additionally, Reynolds and Kaiser operate their own reclamation centers. Each of these companies has its own special remelting facilities which are all out-of-state. For example, Kaiser ships aluminum cans collected in California to its remelting facilities in Washington;[13] Alcoa ships cans to Tennessee and Indiana;[3] while Reynolds ships to Alabama.[13] The reason for shipping cans to these locations instead of selling the scrap cans to local secondary smelters is due to the fact that 90 percent of all aluminum cans are returned to primary production for use in the production of hot metal for canstock sheet. Only 10 percent are consumed by secondary smelters. This information indicates one of the major energy consumption components involved with recycling aluminum cans is scrap transportation.

TABLE 16

ESTIMATED ENERGY USED IN CAN SCRAP TRANSPORT

Destination	Transport Energy*	
	Truck (BTU/Ton)	Rail (BTU/Ton)
Washington	2.19×10^6	0.74×10^6
Tennessee	5.80×10^6	1.83×10^6
Indiana	5.19×10^6	1.69×10^6
Alabama	5.22×10^6	1.66×10^6

*Based upon calculated average distances between:

1. San Jose to Spokane, Washington
2. San Francisco & Los Angeles to:
   - Alcoa, Tennessee
   - Warrick County, Indiana
   - Sisterhill, Alabama

Average transport by truck to export site:

DESTINATION	AVERAGE DISTANCE (MILES)	ENERGY USE ($\times10^6$ Btu/ton)
San Jose	270	0.65
San Francisco	278	0.67
Los Angeles	158	0.38

Average Transport by Rail to Manufacturer:

FROM	DESTINATION	DISTANCE (MILES)	ENERGY USE ($\times10^6$ Btu/ton
San Jose	Washington	1028	0.74
San Francisco	Indiana	2434	1.75
Los Angeles	Indiana	2272	1.64
San Francisco	Alabama	2551	1.84
Los Angeles	Alabama	2118	1.52
San Francisco	Tennessee	2720	1.96
Los Angeles	Tennessee	2363	1.70

Average total transport, assuming that for every ton transported to Washington, two-thirds of a ton will be transported from Los Angeles to each eastern location and one-third of a ton will be transported from San Francisco to each eastern location , is 1.98×10^6 Btu/ton. This value is based on:

for Washington, 1.39×10^6 Btu/ton,
for the three eastern locations, averaged, 2.17×10^6 Btu/ton,and,
for a California average,
$(1.39\times10^6 + (2.17\times10^6 \text{ Btu/ton}) \times 3) \div 4 = 1.98 \times 10^6$ Btu/ton.

The Aluminum Association reports that the energy required for transportation is estimated to be 400,000 Btu per ton of scrap aluminum cans.[7] This figure does not take into account the amount of energy required to transport the scrap from the household to the collection center. Separate curbside collection is assumed with some initial material processing. This energy is 0.31×10^6 Btu/ton scrap.

If California supplied a ton of scrap aluminum to each of these remelting facilities, the estimated energy consumed would be as shown on Table 16.[3,14,15]

B. Processing Recycled Aluminum Cans

TABLE 17

CHEMICAL ANALYSIS - COMMONLY USED ALLOYS IN CONSUMER PRODUCTS[1]

	Si	Fe	Cu	Mn	Mg	Zn	Ti	Others Each	Others Total	Used
1235[2]	.65Si+Fe	---	.05	.05	.05	.10	.03	.03	---	Printed Foil
3004	.30	.7	.25	1.0-1.5	.8-1.3	.25	---	.05	.15	Can Bodies
5182[3]	.20	.35	.15	.20-.50	4.0-5.0	.25	.10	.05	.15	Can Ends, Auto Body Sheet
8079	.05-.30	.7-1.3	.05	---	---	.10	---	.05	.15	Household [illegible]
3003	.6	.7	.05-.20	1.0-1.5	---	.10	---	.05	.15	Frozen Food Dishes
3105[4]	.6	.7	.30	.30-.8	.20-.8	.40	.10	.05	.15	Lawn Chairs, Siding
6063[3]	.20-.6	.35	.10	.10	.45-.9	.10	.10	.05	.15	Extrusions
380[5]	7.5-9.5	1.3	3.0-4.0	.50	.10	1.0	---	---	.50	Die Castings
2036[3]	.50	.50	2.2-3.0	.10-.40	.30-.6	.25	.15	.05	.15	Auto Body Sheet
5657	.08	.10	.10	.03	.6-1.0	.03	.10	.02	.05	Bright Auto Trim
7016	.10	.10	.6-1.4	.03	.8-1.4	4.0-5.0	.03	.03	.10	Bumpers
390	.6.0-18.0	1.3	4.0-5.0	.10	.45-.65	.10	.20	.10	.20	Engine Blocks

(1) Aluminum Association Limits - Shown as either a range or a maximum
(2) 99.35% min. aluminun required
(3) Also allows .10 max Cr
(4) Also allows .20 max Cr
(5) Most commonly used die casting alloy - variations of this alloy allow up to 2% Fe, up to 3% Zn, and up to .35% Sn

SOURCE: "Recovery of Nonferrous Metals from Solid Wastes" by Robert F. Testin, Reynolds Metals Co., Richmond Virginia, Presented at Americans Institute of Chemical Engineers, Symposium on Recycling, Atlantic City, New Jersey, Aug. 29 - Sept1, 1976

Smelting of recycled aluminum cans involves mechanical treatments to reduce the cans into a form suitable for handling, and chemical treatments designed to remove foreign materials (impurities such as salts, oils, and other organics). Smelting is followed by remelting and nominal refining. Composition of the final product is normally adjusted during melting by blending and alloying to produce a product meeting specifications (see Table 17).

1. Presmelting Preparation of Cans

A variety of pretreatments are conducted depending upon the quality of the can scrap. The following are the standard treatments that the recycled cans are subject to:

a. Separation - the scrap must be segregated by composition and type of prior to transport, i.e., cans are separated from other types of aluminum scrap and from other types of wastes, either by hand-sorting at aluminum recycling centers or by the types of front end systems which are found at high-technology resource recovery centers.

High-tech front end separation of aluminum is accomplished with an eddy current separator or a linear induction motor. Because this process cannot be considered exclusive of the remainder of the systems, no energy value is presented.

b. Shredding or Baling - Mechanical reduction of the scrap cans into a denser form makes it easier for transportation and for resmelting. Shredded aluminum cans are usually transported by rail while whole cans are transported by truck. Shredding may take place both at the collection point and at the smelters. Aluminum is frequently crushed prior to transport to increase density.

The Aluminum Association reports the average shredding energy to be 1.94 x 10^6 Btu per ton of aluminum product, which includes some reshredding at the primary smelter as mentioned above.[7]

2. Smelting Process

Prior to smelting, the scrap aluminum cans are delacquered to remove the lacquer coating, salts, oils, and other contaminants by placing the scrap cans into a furnace and heating them to an intermediate temperature (below the melting temperature).

Reverberatory furnaces fired with natural gas or oil are universally used to refine scrap aluminum cans. The furnaces, ranging in capacity from 30,000 to 200,000 pounds of molten metal, have one or two external charging wells (charging the scrap) which are separated from the main hearth of the furnace by a refractory wall known as a "hot wall". The hot wall has two openings, connecting the hearth and the charging wells, which are covered with a skim gate to prevent scrap and skimmings on the molten metal surface from getting inside the furnace. Heat is conveyed from the burner flame by convection and radiation from the roof and sidewalls to the molten metal inside the furnace hearth, and by convection, radiation, and conduction to the scrap in the charging wells.[7]

Scrap is charged to the furnace either manually or mechanically. A typical charge to the furnace consists of 35 percent virgin and 65 percent scrap derived from such sources as internal scrap, customer scrap, and discarded cans. It is important to note that the discarded can fraction is the smallest of these scrap fractions, about seven percent.[7]

Table 18 indicates the compositional changes in charges to the furnace which may occur with increases in recycling. As shown, 7.3% of the recycled aluminum is lost in handling. Melt loss of 6.6% (2.9% on a cast ingot basis) would result in a requirement of 0.140 pounds of primary metal per pound of aluminum in the finished can, even if 100% of the cans were recycled.[6]

TABLE 18

WEIGHT COMPOSITION (POUNDS) GIVEN LEVEL OF RECYCLED ALUMINUM IN FURNACE

% Recycling	Recycled Can	Primary Metal	Total
0	0	1.066	1.066
30*	0.278	1.788	1.066
50**	0.463	0.603	1.066
70***	0.648	0.418	1.066
100	0.926	0.140	1.066

* Low range projection for 1980
** Low range projection for 1985
*** High range projection for 1985

Source: Energy Content in Aluminum Cans, Historical Performance and Future Potential, Report No. 2, the Aluminum Association, Inc., September 15, 1976.

A "molten heel" — molten metal of known composition that occupies the bottom of the furnace and is left over from the previous heat — can be used to shorten the heat time. If a liquid heel is not maintained in the furnace from heat to heat, heavy solids (virgin and scrap) are charged into the furnace, generally through the side doors. Once charged, the material must be completely melted, skimmed, sampled, and assayed before other materials can be charged. Scrap subsequently is charged through the forewall. After each charge, the slag is skimmed off the metal and sampled to determine its composition. It is normally economical to minimize the need for using alloying elements, such as copper, silicon, manganese, and magnesium by charging scrap as close in composition as possible to the alloy being produced.[7]

There are 5.91 Btu per ton of shredded cans expended in melting, delacquering plus in-house transportation, loading, and space heating. (Assuming 100 percent recycled scrap is used.) Because it takes 1.07 tons of shredded cans to produce one ton of aluminum product, the energy value is 6.32×10^6 Btu expended per ton of aluminum produced.

TABLE 19

COMPARISON OF ENERGY CONSUMPTION
VIRGIN MATERIALS vs. RECYCLED CANS

Energy Used to Produce Ingot from 100% Calif. Recycled Can Scrap

Process	Material Required[1] (Tons)	Energy Expended/ (Btu x 106/Ton Product)
Collection & Shredding[2]	1.07	2.27
Transportation	1.07	1.98
Delaquering & Melting	1.07	6.32
		10.57

Energy to Produce Cans from 100% Recycled Cans

Process	Material Required[1] (Tons)		Energy Expended/ (Btu x 106/Ton Product)
Shredding, Transportation and Delaquering	.926		9.79
Virgin Material Input	.140		6.54
Virgin Processing (3)	.140		28.73
Casting to Can Manufacture[4]	1.000		61.62
		TOTAL	106.69

Energy saving in aluminum can production = 66.0%

Notes·

1) Based upon 1.00 ton of aluminum cans as finished product.

2) Separate curbside collection assumed with shredding: (0.31 x 10^6 Btu/ton x 1.07 ton scrap/ton aluminum) + 1.94 x 10^6 = 2.27 x 10^6.

3) Includes Bayer and Hall-Heroult Processes.

4) Landfill residue energy (7% x 0.23 x 10^6 Btu/ton) is included.

C. Summary of Energy Consumption

As shown in Table 19, the largest single use of energy is involved in the delacquering and melting of the recycled cans. The next largest use is involved with the transport of the cans.

V. Conclusions

Aluminum production is unusual in the fact that is very energy intensive when using virgin materials, but when using recycled aluminum the energy requirement is drastically reduced. Using virgin materials requires approximately 252 x 10^6 Btu to produce a one ton ingot, most of which is consumed during the Hall-Heroult process. Using 100 percent scrap or recycled aluminum cans from California in the same process required approximately 11 x 10^6 Btu per ton of ingot, producing potential energy savings of approximately 96 percent. (The energy consumed in each step of the processes is identified in Table 19.) This energy savings is due to the fact that many of the material inputs and their associated energy costs are essentially bypassed. However, the idea of any energy savings of 96 percent must be tempered with the fact that, according to the Bureau of Mines Information Circular 1978/8781, a current typical charge to the furnace consists of 35 percent virgin aluminum and 65 percent scrap derived from such sources as internal scrap, customer scrap, and discarded cans. The discarded cans comprise approximately seven percent of this scrap fraction.

Assuming that energy savings from cans is the same as any energy savings from other types of scrap, aluminum cans represent approximately 5 percent of the total (96 percent) energy savings. This percentage could increase in the future with increased recycling efforts. Therefore, it would be desirable to supplement or substitute the virgin aluminum supply with recycled aluminum to the maximum possible extent, reducing energy consumption as much as possible.

The aluminum can manufacturing process (from ingot production to can manufacture, including shipping) requires an additional 62 x 10^6 Btu per ton can product. The total potential energy savings from virgin materials to 100% recycled cans is thus 313.6 x 10^6 Btu/ton can vs. 106.7 x 10^6 Btu/ton can or 66.0%.

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SECTION 4 - NEWSPRINT

I. Introduction

According to Ayer's "Directory of Publications", over five and one-half million newspapers are published daily in California; almost two and one-half million are published on Sundays.[1] Based on these figures and assuming that 2,500 newspapers weigh approximately one ton, over 54,000 tons of newspapers are produced in California each month.

The ten largest newspapers in California account for circulation over one-half the total of the dailies and essentially all of the Sunday editions. Each week these ten major newspapers use approximately 1,550 tons of 100 percent recycled newsprint.[1] This represents approximately 12 percent of the total volume of newsprint used by them each week. Currently in California, there is only one manufacturing plant producing newsprint, and the product newsprint is 100 percent recycled.

Used newsprint is recovered from the waste stream, shipped to the papermill where it is pulped, cleaned several times, and deinked. The pulp is then converted into newsprint in much the same process that is used with pulp from 100 percent virgin stock.

The production of both 100 percent recycled newsprint and combinations of recycled and virgin pulp in newsprint production is expanding. According to industry representatives, mixed mills and 100 percent recycled mills are planned for development on the west coast in the near future.

II. Methodology

The types and amounts of raw materials used in newsprint production, the types of processes used, and modes and distances of transport of the newsprint were determined from information gathered in phone conversations with papermills which supply the California newspapers.[2] This information, combined with information from newspapers and other sources, was used to determine energy consumption in newsprint production and transport of the product to California newspapers. The California newspapers use paper from mills in Oregon, Washington, and Canada. Energy consumption figures have been calculated for transport of raw materials, production, and transport of the final product to newspapers with the largest circulations in California, representing more than 65 percent of newsprint used in the State.[1]

III. Newsprint Using Virgin Materials

A. Harvest and Transport to Mill

The raw materials utilized in the production of newsprint include both roundwood and sawmill residue in varying proportions dependent upon raw materials and availability and economics. The means of transporting the raw material to the mill are very site specific and include barge, rail, and truck.

For the Pacific Northwest mills surveyed, either barge or rail is used for long haul distances while for the short distances (around 25 miles) a truck is used.

Roundwood requires harvesting and transport to the papermills, while sawmill residue does not directly require harvesting and is usually on site or shipped only a short distance. According to J. Edwin Moore of the American Pulpwood Association, there is very little roundwood that is actually harvested specifically for use in paper production. Most roundwood that is used in paper production is residue from lumber of plywood production.[3]

Several studies have been done concerning energy consumption in logging and transport in the south, eastern, and northeastern United States and Western Canada.[4] These studies are not applicable to the Pacific Northwest due to major differences in harvesting and transport technique. This area is unique due to the large proportion of sawmill residue and small amount of roundwood harvested specifically for paper production.

Based on the telephone interviews with representatives of the papermills which supply the California newspapers, the energy cost for the transport of raw material to the paper mill is quite variable and site specific. The method of harvesting varies, the distance to the papermills varies constantly, the method of transport varies, and many papermills use large amounts of sawmill residue.

From the limited information available from the various mills surveyed, energy costs for raw material transport can range anywhere from 0.054×10^6 Btu/ton to 1.68×10^6 Btu/ton where in one instance small quantities of chips were trucked 350 miles. Generally, however, the available data indicate that the average energy costs would be in the lower portion of this range, about 0.2×10^6 Btu/ton or raw material transported. Energy costs for transport have been determined on a one-way basis for barge and rail, and on a round-trip basis for truck.

Because sawmill residue and roundwood used in papermaking in the Pacific Northwest are by-products of other processes, no energy consumption value is attributed to raw material harvesting.

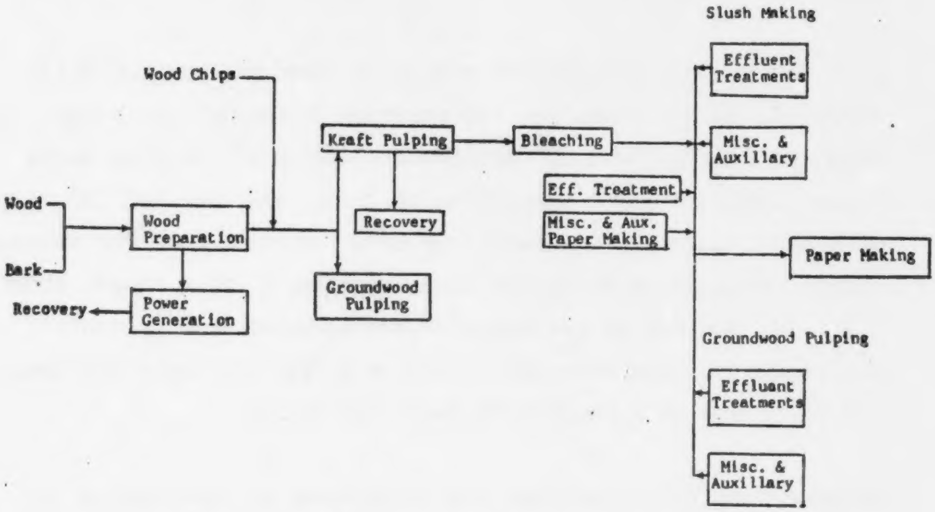
The determination of the quantity of raw materials required to produce one ton of product newsprint is based on an integrated mill utilizing a 75% roundwood to 25% sawmill residue mixture. Such a mill would require 0.928 dry tons of roundwood plus 0.538 dry tons of residue to produce one ton of newsprint. Assuming a 50% moisture content for roundwood or sawmill residue, 2.93 tons of raw materials must be transported to the mill for each ton of newsprint produced. The total energy cost for raw material transport per ton of newsprint produced is therefore (2.93) $\times$ (0.2×10^6 Btu/ton) or 0.59×10^6 Btu/ton.

B. Newsprint Production

There are no mills in California which produce newsprint from virgin stock. The major source of newsprint used by the 10 largest newspapers in the state are mills from Oregon, Washington, and British Columbia. Small amounts are imported from Texas and Arizona. The paper from Arizona is made from a mix of 20 to 30 percent recycled news and 70 to 80 percent virgin stock.[5]

FIGURE 8

NEWSPRINT PRODUCTION USING 100% VIRGIN MATERIALS



Slush Making
Effluent Treatments
Wood Chips
Kraft Pulping
Bleaching
Misc. & Auxilary
Eff. Treatment
Wood
Wood Preparation
Recovery
Misc. & Aux. Paper Making
Paper Making
Bark
Recovery
Power Generation
Groundwood Pulping
Groundwood Pulping
Effluent Treatments
Misc. & Auxilary

Source: Gordian & Associates, Inc., The Potential for Energy Savings in Nine Selected Industries, June 1974.

"The Potential for Energy Saving in Nine Selected Industries", a report published by Gordian and Associates, Inc., provided a description of newsprint production.[6] Figure 8 provides a detailed diagram of the paper making process. Newsprint production consists of six steps:

- Pulpwood acquisition (harvesting of roundwood and obtaining sawmill residue);
- Debarking of roundwood;
- Chipping of roundwood;

- Pulping (chemical, mechanical, thermomechanical);
- Pulp bleaching;
- Paper production.

Logs, called roundwood, require logging and transport to the pulpmill while sawmill residue, chips and sawdust, requires transport from the sawmill to the pulpmill. Roundwood must be debarked. Northwest papermills usually use hydraulic debarking, a high pressure waterjet to separate the bark from the log. This removes approximately 12 to 15 percent of the weight. The bark may be used for mechanical pulp, but often is not. In this process approximately two percent of the roundwood weight is lost.

Roundwood and sawmill residues are then used to make pulp. As mentioned before, mechanical pulp (often called groundwood) can be made from either chipped or unchipped roundwood, or sawmill residue. Groundwood pulping is the physical process of grinding the wood into pulp. Kraft pulping requires the addition of chemicals, high temperatures, and pressure to digest the wood. Wood still must be chipped for kraft pulping. Chemicals used in this process precipitate a black liquor which is recovered and which provides a valuable source of heat and power.

Thermomechanical pulping, as discussed in Appendix C, is another method of pulping which is becoming widely used in newsprint production as a replacement for kraft pulping. This method is more efficient in many aspects than either kraft or groundwood pulping due to less loss of wood, larger fibers, cleaner production methods, and less expensive processing.[7]

The pulp is then bleached. Groundwood pulp is brightened with peroxides or hydrosulfites. Kraft pulp is bleached to remove light absorbing substances such as lignins, resins, and noncellulose materials by using chlorine, chlorine dioxide, and hypochlorites.

The pulps are then mixed, usually in a 75 percent groundwood to 25 percent kraft ratio, with fibers, additives, and water. This mixture is then put onto a web or screen form. The water is removed and a sheet is formed by pressing between a long row of rollers. The sheet is then dried by applying heat to the sheet while it is moving through the rollers. Paper sheet is rolled onto large rolls that are cut, wrapped, and shipped to buyers.

Though the Gordian Associates study presented energy consumption figures for each step of the paper making process, these figures are based on newsprint production in the Northeast and are not applicable to production in the Pacific Northwest. The overall energy use figures presented in this report are based on telephone conversations with representatives of west coast mills and data presented in Post 1978 Pulp and Paper Directory.[8]

The energy consumed at the mill in newsprint production from virgin materials is summarized in Table 20. Fuel used in paper production includes electricity, oil, and natural gas, sawdust, chips and barks. The weighted average amount of energy, as defined in that table, required to produce one ton of newsprint is 19.94×10^6 Btu. However, as seen in this table, there is a variance, from mill-to-mill, of energy requirements on a per-ton produced basis. The differences are due to variables in newsprint produced, type of raw materials used, and the type of pretreatment and pulping.

The proportion of sawmill residue used in paper production is growing rapidly. Projections indicate that the trend toward increased use of sawmill residue in west coast operations will continue. This trend is due to the large amounts of residue available from sawmill activity and the fact that much of the roundwood is being used for other wood products.[6] Since sawmill residue does not require harvesting and transport of raw materials, debarking, newsprint production using the residue is less energy demanding.

TABLE 20

ENERGY CONSUMPTION IN PAPER PRODUCTION

Mill Production	Energy Consumption				Total Energy Consumption	BTU/Ton
	Purchased			In House		
	Electricity	Natural Gas	#6 Fuel Oil			
#1 750TPD	1,800KWH/Day	-	80,000GPD	Bark - 300 TPD	$14,598 \times 10^6$ BTU/Day	19.46×10^6 BTU/Ton
#2 1760TPD	1,661.15 MWH/Day	-	70,000GPD	Hog Fuel - 630TPD	$34,113 \times 10^6$ BTU/Day	19.38×10^6 BTU/Ton
#3 1480TPD	1,289.75 MWH/Day	-	17,000GPD	Bark - 850 TPD	$25,670 \times 10^6$ BTU/Day	17.34×10^6 BTU/Ton
#4 285TPD	-	-	36,750GPD	Hog Fuel- 178TPD	$6,852 \times 10^6$ BTU/Day	24.04×10^6 BTU/Ton
#8 630TPD	4.93×10^9 BTU/Day	3.37×10^9 BTU/Day	9.86×10^8 BTU/Day	3.2×10^9 BTU/Day	$12,493 \times 10^6$ BTU/Day	19.83×10^6 BTU/Ton
#10 425TPD	3.67×10^9 BTU/Day	2.19×10^9 BTU/Day	1.04×10^9 BTU/Day	3.6×10^9 BTU/Day	$10,520 \times 10^6$ BTU/Day	24.75×10^6 BTU/Ton
[illegible] 1200TPD	551 MWH/Day	1.6×10^{10} BTU/Day	-	Bark - 368 TPD	$25,980 \times 10^6$ BTU/Day	21.65 x 10 BTU/Ton

Notes:
1) 11,100 BTU converts to 1 KWH
2) 1 Barrel #6 Fuel Oil (42 gallon) equivelent to 6×10^6 BTU
3) 1 Ton bark equivelent to 10.5×10^6 BTU
4) Hog Fuel @ 4500 BTU/lb.

Weighted average = 19.94×10^6 BTU/Ton

The type of pulping can also cause differences in energy consumption. Mills have traditionally used an approximate ratio of 75 percent of groundwood pulp and 25 percent chemical pulp. However, because of the numerous advantages of thermochemical pulping, as discussed in Appendix C, there is a trend toward replacing the expensive chemical pulp with the thermomechanical pulp.

C. Transport to Newspaper Printing Facilities

Newsprint is shipped to California via barge, rail, and truck from several locations on the Pacific North Coast, Texas, and Arizona. Mills supplying California newspapers with newsprint were located, and the distance to newspaper locations were calculated. Energy expenditures for the transport of newsprint from the various paper mills supplying the ten largest California newspapers were determined and are assumed to be representative. If a newsprint is shipped by rail, a Southern Pacific Railroad Map was used to calculate the distance; if the newsprint is transported by truck or barge, a Rand McNalley map was used to determine the distance.

Table 21 shows the distances, method of shipment, tonnage and energy requirements for the transportation of newsprint from the mills to the California newspapers. This data is summarized into averages for the central, northern, and southern regions of the State. Average energy costs per ton for newsprint transport range from a low of 0.569 x 10^6 Btu/ton for newspapers located in central California to a high of 0.813 x 10^6 Btu/ton for those located in Southern California. Statewide, the weighted average energy expenditure is 0.759 x 10^6 Btu/ton.

IV. Newsprint Using Secondary Materials

A. Materials Transport

The 100 percent recycled newsprint is produced from newsprint recovered and collected from all over California and Arizona. The newsprint is hauled by truck from the point of collection to the papermill.

When considering the energy expended in collection of the recovered newsprint, it should be noted that were the newsprint not recovered and reused, it would become part of the waste stream requiring energy for collection, processing, and landfilling. The recycled newsprint also has an advantage over 100 percent virgin newsprint in that there is no harvesting or pretreatment of the material which is often necessary with 100 percent virgin stock.

Table 22 identifies the quantities of newspapers backhauled. In this case, backhauling by truck involves delivery of newsprint from the mill to the newspaper facility and subsequent pick-up

TABLE 21

ENERGY REQUIREMENT FOR TRANSPORT OF NEWSPRINT TO CALIFORNIA NEWSPAPERS

Central Region

Mill Shipped From	Miles Shipped	Method Shipped	Tons/Week	10^6 BTU/Ton	10^6 BTU/Week
1	900	rail	88	.652	57.38
2	1189	barge	87	.642	55.85
3	1099	barge	88	.593	52.18
6	734	rail	87	.531	46.20
7	590	rail	87	.427	37.15
Total	4512		437		248.76
Average	902		87		

Weighted Average = 248.76 ÷ 87 = 0,569 x 10^6 Btu/ton

Northern Region

Mill Shipped From	Miles Shipped	Method Shipped	Tons/Week	10^6 BTU/Ton	10^6 BTU/Week
1	962	barge	339	.519	175.94
	980	rail	473	.709	335.35
2	1137	rail	98	.823	80.65
	1162	barge	1059	.627	663.99
5	1211	barge	871	.654	569.93
6	847	truck	95	2.033	193.13
	797	rail	439	.577	253.30
Total	7096		3374		2272.29
Average	1014		843		

Weighted Average = 2272 ÷ 3374 = 0.673 x 10^6 Btu/ton

Southern Region

Mill Shipped From	Miles Shipped	Method Shipped	Tons/Week	10^6 BTU/Ton	10^6 BTU/Week
1	1347	barge	298	.727	216.65
2	1506	barge	891	.313	724.38
3	1468	barge	1092	.793	865.96
4	1713	barge	794	.925	734.35
5	1254	barge	298	.677	201.75
6	1148	rail	351	.831	291.68
8	960	rail	794	.695	551.83
9	1000	rail	794	.724	574.83
10	960	rail	794	.695	551.83
11	1558	rail	794	1.128	895.63
Total	12914		6900		5609.02
Average	1291		690		

Weighted Average = 5609.02 ÷ 6900 = 0.813 x 10^6 Btu/ton

Weighted State average = 0.759 x 10^6 Btu/ton

Btu/ton based on:
Barge 540 Btu/ton mile
Rail 724 Btu/ton mile
Truck 2400 Btu/ton mile

Assume 100% backhaul

Mileage determined from Rand McNalley or Southern Pacific Railroad Map.
Volumes and shipping methods provided by newspaper representative.

TABLE 22

ENERGY CONSUMPTION IN TRANSPORT OF OLD NEWSPRINT TO PAPERMILL

LOCATION SHIPPED FROM	TON/MONTH PROVIDES	METHOD OF SHIPMENT	% BACKHAULED	DISTANCE SHIPPED	BTU/TON X 10^6
Arizona	700	truck	100%	640 miles	1.536
Bay Area	1500	truck	30 %	406 miles	0.974
Sacramento	300	truck	0 %	417 miles	1.001
Los Angeles	7100	truck	25%	30 miles	0.072
San Diego	1900	truck	0%	99 miles	0.238

Total 11,500 TPM

Weighted Average = 0.330×10^6 BTU/TON

and delivery of old newspapers to the mill. Backhauling is not considered in the energy expended in transport, but it is included as information.

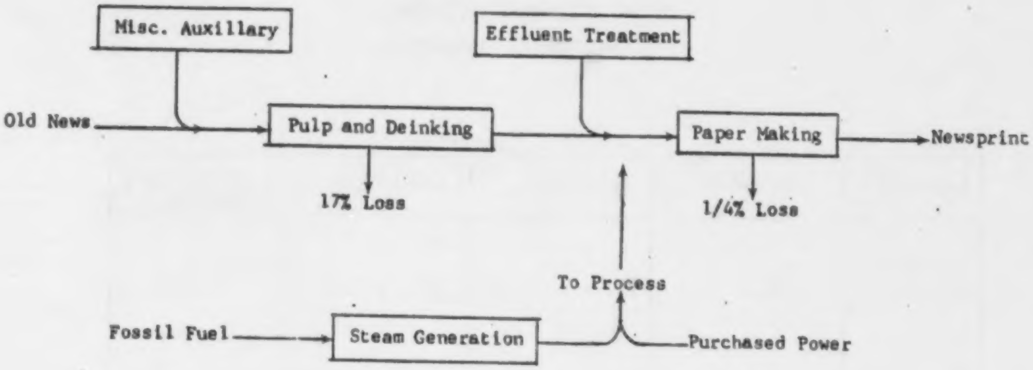
Table 22 also identifies the energy consumed in transport of old newspaper to the paper mill based on conversations with industry representatives. As it can be seen, the energy requirement for the transport of material varies from 0.072×10^6 Btu per ton for local collection, to 1.526×10^6 Btu per ton for transport from the most distance source. These figures are based on 2,400 Btu/ton-mile for truck transportation.[9] The weighted average is 0.33×10^6 Btu/ton of old newsprint transported.

B. Production

A diagram of the production process for newsprint from 100% recycled news is shown in Figure 9. When the recovered newsprint arrives at the papermill it is checked carefully to make sure there are no contaminants such as plastics, metals, string, magazines or colored paper or other materials that will interfere with the paper production process.

FIGURE 9

NEWSPRINT PRODUCTION USING 100% RECYCLED NEWS


Misc. Auxillary
Effluent Treatment
Old News
Pulp and Deinking
Paper Making
Newsprint
17% Loss
1/4% Loss
To Process
Fossil Fuel
Steam Generation
Purchased Power

SOURCE: Gordian & Associates, The Potential for Energy Savings in Nine Selected Industries

The paper is then fed into pulpers. Water and chemicals are added to clean, remove all the unwanted contaminants and ink, and breakdown the paper into fibers. The mixture then goes through an intricate cleansing process becoming a clean pulp used to produce newsprint in the same process as pulp from virgin stock is converted into newsprint.

Recycled newsprint tends to be somewhat weaker than newsprint made from 100 percent virgin stock, but has the same brightness and texture as the virgin newsprint. This characteristic weakness results because in the repulping of newsprint, the fibers are broken into shorter lengths. The tensile strength of newsprint, directly related to the fiber length, is less in recycled newsprint with its shorter fibers than in virgin newsprint which has longer fibers.

Some printing machinery in newsprint operations may have problems with breakage because of the fiber weakness, but based on phone conversations with newspaper company representatives, this does

TABLE 23
ENERGY CONSUMPTION IN TRANSPORT OF NEWSPRINT USING SECONDARY MATERIALS TO CALIFORNIA NEWSPAPERS

Central

Papermill	ton/week[3]	Btu/ton[4]	Distance	Shipping Method[5]
#1 100% Recycled	86.7	1.0×10^6	417 miles	truck
#2 30% Recycled	-	-	-	-

Southern

Papermill	ton/week[3]	Btu/ton[4]	Distance	Shipping Method[5]
#1 100% Recycled	817.7	0.156×10^6	65 miles	truck
#2 30%	887.8	0.462×10^6	638 miles	rail

Northern

Papermill	ton/week[3]	Btu/ton[4]	Distance	Shipping Method[5]
#1 100% Recycled	318.7	0.974×10^6	406 miles	truck
#2 30%	-	-	-	-

Weighted Average = 0.443×10^6 BTU/Ton

[1] Energy figures provided by industry representative
[2] Volumes supplied by industry representatives
[3] Volumes supplied by newspaper representatives
[4] Btu/ton for transport based on: 2,400 Btu/ton mile for truck, 724 Btu/ton mile for rail
[5] Method of shipment provided by industry representatives

not seem to pose a major problem in the printing process. The recycled paper represents an acceptable substitute for 100 percent virgin stock.

Some California newspapers use newsprint produced from a combination of virgin stock and recycled newsprint. As shown in Table 23, almost 900 tons of 30 percent recycled newsprint are used each week by the 10 largest California newspapers.

The paper making process uses a combination of recycled paper pulp and virgin pulp. There are no energy values for production available for this process. However, a report by A.D. Little, Inc. states that a combination of virgin and recycled pulp is economically less attractive than 100 percent recycled, but more economical than 100 percent virgin stock newsprint.[10] There is a definite trend toward using more recycled newsprint, either in combination with virgin pulp, or by itself. This is indicated by the increased development of recycled newsprint plants in Oregon.

Based on conversations with industry representatives, an estimated 15.54×10^6 Btu is required to produce one ton of newsprint from secondary fibers. This value was derived based on 350 tons per day of old newspapers being processed to produce 300 tons per day of newsprint using an average of 670 kwh of electricity and 6,070 pounds of steam per ton product. Calculations are based on a) 11,100 Btu to produce 1 kwh and b) 50 psig process steam with boiler efficiency of 85%. The production of newsprint from recycled fibers consumes 22 percent less energy than the production of newsprint from 100 percent virgin stock.

C. Transport to Newspaper Printing Facilities

The newsprint is shipped to buyers by truck and rail. Table 23 provides a breakdown, by northern, central, and southern regions of California, of the amount being shipped, method of shipment, and energy requirements for transport of the product.

The weighted average energy consumption is 0.443×10^6 Btu per ton of newsprint transported. Comparing the regional values for transporting newsprint from virgin stock mills (Table 21) with that from recycled stock mills (Table 23) demonstrates the high energy consumption of trucks compared to rail and waterway. The average energy consumed in transporting newsprint from virgin stock to northern California, an average of 1,014 miles by barge and rail, is 0.673×10^6 Btu per ton. The estimated energy expended in transporting newsprint in Northern California by truck, an average distance of 406 miles, is 0.974×10^6 Btu per ton. This energy value is about 40 percent greater, yet the distance is one-third to one-half as great.

V. Conclusion

The major energy savings in using secondary materials as compared to virgin materials in the production of newsprint is realized in the manufacturing process, where only 15.54×10^6 Btu/ton is required as compared to 19.94×10^6 Btu/ton, a net energy savings of 22%.

Energy costs associated with the transport of raw materials (virgin or old newsprint) and product newsprint are very site-specific and reflect a small percentage of the total energy costs. Mill siting with respect to raw material sources or newsprint buyers will measurably effect the economics both in terms of transport distance and transport methods available.

Tables 24 and 25 show the energy costs associated with the production of newsprint from virgin raw materials and secondary materials, respectively. Energy to produce 100% recycled newsprint requires 16.74×10^6 Btu/ton as compared to 21.29×10^6 Btu/ton for newsprint produced from virgin materials, an overall energy savings of 4.55×10^6 Btu/ton or 21.4%.

TABLE 24

NEWSPRINT ENERGY CONSUMPTION USING VIRGIN MATERIALS

Process	Amount Required/Tons	Energy Used ($x10^6$ Btu/Ton)
Harvesting[1]	2.93	N/A
Transport to Manufacturer[2]	2.93	0.59
Newsprint manufacturing	2.93	19.94
Transport to Newspapers	2.93	0.76
Landfill residue[3]	-	-
		21.29

Notes:

1) Harvesting energy not considered because source material is considered secondary to sawmill lumber product.

2) Roundtrip is assumed due to specialized transport (no backhauls).

3) Negligible residue.

TABLE 25

ENERGY CONSUMPTION IN NEWSPRINT PRODUCTION USING RECYCLED NEWSPRINT

Process	Amount Required/Tons	Energy Used[2] ($x 10^6$ Btu/Ton)
Residential Collection[1]	1.17	0.36
Transport to Manufacturer	1.17	0.39
Newsprint Manufacture	1.17	15.54
Transport to Newspapers	1.00	0.44
Landfill Residue	0.17	0.01
		16.74

Energy Savings using recycled newsprint vs virgin materials is 21.4%.

Notes:

1) Separate curbside collection assumed.

2) Based on 1 ton of finished product.

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SECTION 5 - FERROUS CONTAINERS

I. Introduction

Ferrous metals appear in the solid waste stream in such forms as junked vehicles, steel cans, and ferrous components of consumer appliances. Ferrous constitutes approximately seven percent of municipal solid waste (excluding automobiles). As shown in Table 26, about 50 percent of the ferrous fraction is steel cans.[1] The demand for production of cans is predicted to increase at 3.3 percent per year through 1980. After 1980, growth will slow to 1.7 percent per year.[2] In addressing the energy comparison of steel made of virgin ores or recycled steel, the scope of this study was limited to determining if municipal ferrous, specifically steel cans, is being recycled back into steel cans. Table 27 outlines the major uses of steel cans in the U.S. in 1972. Our findings have shown that there is only a small number (exact number is indeterminate) of steel cans that are recycled into steel cans.

II. Methodology

In determining the feasibility of recycling ferrous consumer by-products, there were certain problems that had to be examined. A research probe indicated that there were such factors as the different types of scrap and steel cans, current and future supply and demand, and limited availability of markets for steel scrap to be considered.

III. Types of Scrap

There are three types of scrap differentiated by their source: (1) home or mill revert scrap, which is generated during the production of iron and steel; (2) prompt industrial scrap, which is generated during the fabrication of mill products into consumer and industrial products by the metalworking industries; and (3) obsolescent scrap,

TABLE 26

FERROUS METAL IN MIXED MUNICIPAL WASTE, 1972 to 1990

(In thousand tons)

Source and Type	1972	1975	1980	1990
Cans:				
Households	4,604	4,650	4,770	5,020
Commercial/ Institutional	916	935	958	1,010
Industrial	40	40	42	45
Total cans	5,560	5,625	5,770	6,075
Other Ferrous Metal	3,705	4,245	5,315	7,425
Total Ferrous Metal	9,265	9,870	11,085	13,500
Litter (unrecovered)	30	32	36	40
Percent cans (excluding litter)	60	57	52	45

Source: Midwest Research Institute

TABLE 27

NATIONWIDE STEEL CAN RECYCLING, 1972

(In thousand tons)

	Post-Consumer Waste (1)	Can Plant Scrap (2)	Total
Copper Precipitation	50		
Detinning	4	640	705
Steel Manufacture	11		
Ferroalloys (not applicable to California)	3	—	3
Total	68	640	708

Source: (1) Office of Solid Waste Management Programs, EPA

(2) Midwest Research Institute estimates

the product of value obtained from society's discards. Prompt and obsolescent scrap are known as purchased scrap because collection and processing of this scrap is external to the steel making process. The prompt scrap is usually channeled to a scrap broker who in turn sells it back to the steel producers. The obsolescent scrap is largely collected by local scrap collectors and sold to dealers who process it before selling it back to the producer.

Home, or in-house, scrap is usually consumed within the plant in which it was generated, although some interplant shipments do take place. Prompt industrial scrap likewise moves readily through the recycling process. Obsolescent scrap, however, is not readily returned to the steel production process. This is due to its heterogeneous nature and unknown quality. Only about 60 percent of the obsolescent scrap generated each year is processed and used in the production of net metal. The remaining portion is unfortunately lost to the waste stream.[3]

There are three different types of steel cans: tin cans, bi-metal cans, and tin-free steel cans. The tin can is a steel can with a tin coating to prevent corrosion from acidic food or beverages. The bi-metal can has added aluminum tops for easy open purposes. The newer tin-free cans were developed to lessen the contaminant level in recycling steel cans.

Rigid specifications for steel production require that scrap be processed to remove contaminants and impurities. Recycling of cans presents a special problem because of their contamination from aluminum tops, lead from the can seams, and tin. In periods of peak demand for steel or in scrap metal shortages, the availability and low cost of higher quality raw materials tends to reduce the steelmaker's incentive to use the lower quality scrap.

IV. Recycling Operation

The recycling options for steel cans recovered from mixed waste as shown in Table 27 are copper precipitation, steel remelting and detinning.

Copper Precipitation

The copper industry presently consumes over 500,000 tons per year of light gauge ferrous scrap. The current market is supplied by 260,000 tons of detinned steel; 50,000 tons of post-consumer can scrap, and 190,000 tons of other steel scrap.[4]

Demand is estimated to increase to over 900,000 tons per year by the early 1980's.* Due to the projected decline in tin plate used to manufacture metal cans, the can plant scrap available to detinners will decline in the future. The most logical source available would be recovered can scrap from municipal waste since this material has the desired broad surface area and low density.[4] See Appendix D, Section 1-VII for a breakdown of steel cans in municipal (household) waste.

Steel Mills

It was estimated that in 1972, 34 million tons of iron and steel scrap were purchased by the steel industry for use in manufacture of steel. If all post-consumer can scrap available in the Standard Metropolitan Statistical Area (SMSA's) in 1972 in the U.S. were recovered, it would represent only 11.4 percent of the scrap now used by the industry. Due to limited quantities available on a continuous basis, steel mills are reluctant to use recovered municipal can scrap.[4]

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* New techniques in copper precipitation are being tried which may eliminate the need for scrap steel.

Detinning

Steel cans could possibly be recycled by processing them through detinning operations to remove the tin and lead. This would produce a good grade of scrap steel for the steel mills. Commercial detinners process close to 700,000 tons of steel per year. The tin is removed and the clean steel is sold at an equivalent price to No. 2 bundles.**5

Detinners shred the material and remove the tin by addition of hot caustic soda and sodium nitrate. The chemical reaction forms sodium stannate which is removed and electrolyzed to recover tin. The detinner is limited by the economics of the process and the price of steel and tin. Impurities in the material increase the costs of the chemicals and separation of the tin becomes more difficult.

One of the biggest problems limited the use of recovered cans is the aluminum lids from beverage cans. Caustic soda attacks aluminum producing aluminum oxide which has no value. It also produces hydrogen which can be explosive if aluminum is present in high concentrations. Aluminum substantially increases the cost and makes the detinning process less attractive. If steel cans become available in larger quantities, technology may be developed so that the economics of detinning are much more attractive.

V. Conclusions

The recent development of tin-free steel (TFS) should eventually reduce the problem of tin scrap, primarily in beverage containers. This product utilizes a metallic chromium-chromium oxide film combination. Currently, however, the use of TFS in can steel is progressing

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** Old black and galvanized steel sheet scrap, hydraulically compressed to charging box size and weighing not less than 75 pounds per cubic foot, may not include tin or lead, contact material or vitreous enameled material.

rather slowly. A complete shift to TFS will probably never occur because some food products are too corrosive for the chrome plating. There are varying opinions on how far the use of this type of can will extend.

Nearly all the growth in recent years has been in soft drink and beer containers where metal cans are increasing their share of these markets at the expense of returnable glass containers. Beverage can growth will be high, but will be predominantly in aluminum and plastic, rather than steel.

In addition to limited steel can use, the availability of markets for tin can scrap in California is limited. Due to a decreased price paid for copper and in turn a negative effect on the tin can market, the Los Angeles By-Products tin can scrap operation was closed. Atlantic Richfield purchased from Anaconda its Yerington, Nevada copper mine; but, because prices for copper are depressed and there was a low return on investment, Atlantic Richfield closed this mine. Some of the tin cans recovered by the Los Angeles By-Products facility at Solid Waste Engineering Transfer Station (SWETS) and Sacramento County and marketed by Metals Research Institute (MRI) were sold to this mine. Calls to scrap dealers regarding availability of markets for tin scrap were answered by expressions of concern about the already limited market for cans.

Therefore, due to the limited California markets, the advent of tin-free steel cans, and a questionable supply and demand -- current and future, it is not economically or technically feasible to recycle steel cans back into steel cans. This conclusion therefore precludes an energy comparison of using recycled metal versus virgin materials.

Despite the fact that a universal statewide market for ferrous containers is not available at the present time, industry has indicated that tin free ferrous scrap uses approximately 50% less energy than corresponding virgin material.[7]

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CHAPTER TWO
ENERGY CONSERVATION COST ANALYSIS

I. Introduction

The purpose of this chapter is to identify the capital and average operation costs of equipment and labor required to operate a separate curbside collection system, an integrated curbside collection system, a community drop-off center, and a capital-intensive resource recovery system. Additionally, an analysis of the cost of transporting secondary materials to market by the use of private carriers, P.U.C. regulated carriers, and vehicles owned by recycling centers will be presented.

II. Methodology

A literature search was conducted with respect to existing recycling centers throughout the State and in various parts of the country. These centers were analyzed for cost effectiveness given the type of operation (i.e. drop-off centers, curbside collection center, etc.) the throughput of the system, the equipment used, and the available material markets. In each case, wherever possible, the method of processing material was analyzed in terms of its effectiveness compared to other similar operations.

The majority of information was obtained from grant proposals funded under the State Litter Control, Resource Recovery, and Recycling Act of 1977 (SB 650). Such information included a cost breakdown of expenditures for equipment, public education, and advertising for a variety of resource recovery systems. Many of the proposals contained historical summaries of labor, capital, and operational costs. Data were also collected through personal contacts with manufacturers, materials brokers, recycling centers, transporters, and equipment dealers.

III. General Assumptions

In many cases there was not sufficient information to adequately analyze a particular recycling operation or processing technique. Variation in location, labor requirements, equipment costs and use, local and distant markets, transportation methods, and philosophy made direct comparison ineffective. As such, it was necessary to draw upon the successful elements of these operations and techniques to establish composite systems which would generate the maximum monetary returns for the least cost.

In order to standardize these composite systems, the following general assumptions were made for all systems except the community drop-off center.

A. Material Form

1. Glass - partially crushed and stored as mixed color cullet.
2. Aluminum - shredded and magnetically separated.
3. Newsprint - collected and stacked on 4' x 4' pallets to a height of 4' and then banded for shipment to market. (While stacking and baling of newspapers onto pallets may require additional materials and time, it is felt that until tonnages are quite large, baling is not cost effective given the capital and labor costs. It is cautioned, however, that markets for stacked newsprint should be established, preferably on a long-term basis, before stacking is chosen as a method of processing newsprint. If stacking is not feasible, bulk storage or baling should be investigated as a method of processing.)
4. Ferrous container scrap - collected and temporarily stored. Ferrous container scrap is made up of bi-metal and steel with tin coatings. There is no technology which will separate out the bi-metal (aluminum top closure) containers. There is no market for bi-metal cans but there is a limited market for steel containers with and without tin coating. Therefore,

due to a lack of a stable current market, ferrous scrap is disposed of at a negligible cost.)

Quality control for the above materials is maintained by visual inspection with manual removal of contaminants.

B. Equipment

1. Material storage bins - standard 45 cubic yard roll-off containers.
2. Forklift - four ton capacity with rotating head.
3. Can processor - includes conveyor, magnetic separation, shredder and blower at 500 pounds per hour capacity.
4. Other equipment - includes digital scales and canvas coverings for newsprint.

C. Site

1. One acre of land, fenced and paved.
2. Separate 400 square foot office building (except for integrated curbside collection system).

D. Labor - All labor is paid on a full-time basis.

E. Transportation - All goods are sold F.O.B. seller's yard. All shipments of goods to market are full loads. (Transportation costs, because of their significance, are discussed in a separate section.)

F. Markets - All prices are expressed in 1978 dollars and all goods are sold F.O.B. seller's yard. All profits are before taxes.

G. Financing Terms - The interest rate for financing plant and equipment expenditures is 9% and the down payment is 20%. Equipment purchases are financed for 5 years, whereas site expenditures are financed for 20 years.

H. Start-Up Costs - The various recycling systems to be analyzed will incur certain costs in the process of going into business. The bulk of these "start-up" costs result from the 20% down payment required for site and equipment. Other "start-up" costs include expenditures for insurance, deposits for gas, electric and telephone service, advertising, public education, canvas (newpaper cover) and miscellaneous items. See Appendix D, Section 2 - VIII for details.

SECTION 1 - TRANSPORTATION COSTS

The cost of transporting secondary materials to market can be a significant factor in determining the economic success of a resource recovery operation. In some cases, especially with low priced commodities, the shipping costs may exceed the value of the material being shipped. The recycling center merely ends up providing a public service in recycling these materials and must rely on other materials to generate a profit.

It has been found that the roll-off bin with a capacity of 20 to 50 cubic yards is most frequently used for storage and transport of the various materials. The container can either be carried by a chassis specialized for roll-off bodies or by trailer with a roll-off hoist. Because of the use of this specialized equipment, nearly all motor carrier transportation in the recycling industry is proprietary. This proprietary traffic has been estimated to handle over 90% of the motor transportation of recyclable products, with the remainder being hauled by carriers regulated by the P.U.C.[1]

I. Proprietary Haulers

The secondary material brokers, by the nature of their business, are the major suppliers of roll-off containers and transportation service to the recycling industry. In general, materials are purchased F.O.B. the recycling center yard and the goods are either transported to the broker's yard or to the manufacturer. The roll-off container and transportation to market are provided to the center for a cost in the form of a reduction in the price received per ton of material. Transportation to market can also be provided by a local refuse hauler. This service, however, may be restricted to the operating area of the hauler's franchise and, in most cases, is confined to within city limits.[2] It was found that these haulers charge approximately $35 per hour with a two hour minimum.[3]

The recycling centers, of course, can transport materials to local markets using their own vehicles. Most recycling centers, however, operate on a limited budget, and a capital outlay for the purchase of a transport vehicle of the size necessary to haul material to other than local markets is financially prohibitive. Some recyclers have invested in a small used flatbed truck capable of transporting small volumes of goods to local markets. These vehicles usually incur high maintainance and operating expenses and are unreliable. Analysis of SB 650 grant proposals reveals that many centers desire to purchase more reliable transport vehicles.

II. Carriers Regulated by the PUC

A recent study by the PUC comparing intrastate and interstate motor carrier and rail rates indicates that less than 50 carriers were possible participants in the transportation of recyclable commodities. This number represents less than 0.3% of the total for-hire carriers in California. Approximately 25 carriers were active in the transportation of these commodities and none were obtaining all of their revenue from transporting recyclable goods. While there are only a few carriers who specialize in the transportation of recyclables, some have been able to complement shipments of raw materials and finished products with backhauls of secondary material.[4]

Carriers may apply for deviations from the PUC Minimum Rate Tariffs under Section 3666 of the Public Utilities Code, if the carrier has demonstrated that a rate deviation is justified (i.e. not set below the level where costs cannot be recovered). Historically, scrap paper haulers have been granted rate deviations upon application. Concurrent with the PUC deviation regarding recyclable materials is the ICC MC-85 Special Certificate which allows motor carriers to apply lower rates when hauling recyclable materials interstate.[5]

Rail transportation is not extensively used for the intrastate transportation of recyclable materials. It has been suggested that an inadequate supply of rail cars is indirectly affecting the use of this mode of transport, both intrastate and interstate. It has been noted, also, that because of possible damage to rail cars by the transportation of metal scrap, rail haulers may be reluctant to furnish cars for this type of transport. Centers which are located on rail spurs may have their materials transported by permitted motor carriers at the same rates as if the material was being transported by rail.[6]

III. Transportation Cost Background

A survey of the SB 650 grant recipients revealed that the bulk of material flow is through proprietary haulers. The centers surveyed represent the largest recycling centers in operation around the State. A small fraction of material is transported to local markets via center-owned flatbed trucks. Transportation distance varied from 2 miles to 600 miles round trip with load weight varying from less than 1 ton to 30 tons. The variables considered in the analysis of cost include: distance to market, frequency of shipment, weight per load, form of material (i.e., baled, shredded, loose, etc.), and market price. The majority of the centers contacted negotiate prices F.O.B. the seller's yard.

Unfortunately, when products are marketed F.O.B. seller's yard the cost of transportation is very difficult, if not impossible, to determine because such costs are incurred as a reduction in the price received per ton of material.

In addition, many centers were unable to indicate the market price based on F.O.B. buyer's yard. Even if a center could quote these two market prices, the difference includes a charge for transportation, bin rental and broker's profit (if goods are marketed through a broker). Bin rental charges are set at a fixed monthly rate and thus the per trip bin rental cost varies inversely with usage.

Compounding this factor is the tendency that as bin utilization increases, the price received F.O.B. seller's yard usually increases. This increase may occur for a number of interrelated reasons stemming from the economies of scale. First, as mentioned above, increased bin utilization reduces cost per trip. Second, the price that brokers offer generally increases as tonnages increase. Finally, the price that brokers receive from another broker or manufacturer (which affects their ability to pay) increases as tonnages increase. The effects, therefore, of increased bin utilization and increased tonnages on price cannot be individually ascertained. Brokers' profit cannot be determined because of understandable reluctance to reveal proprietary information, which includes manufacturer's markets and delivered prices.

An attempt was made to calculate the difference in price the manufacturer would pay from the price the center would receive from the broker. Variations of locations, tonnage, and preferential treatment of customers made this analysis futile.

Of course, there are those centers which own their own vehicles and haul to local markets. Because of the variation in the type of vehicles, methods of operation, age, and maintenance costs, an analysis of historical data was found to be of little value.

IV. Analysis

In view of the above shortages of existing data, the analysis of transportation costs was accomplished, by using information reflecting costs associated with vehicle ownership, vehicle rental charges of $35 per hour, and PUC Minimum Rate Tariffs. The analysis is limited to the buy-back center and to the separate curbside collection system with aluminum buy-back because of their profitability and their larger material volumes (please see section 2 of this chapter for descriptions of these recycling operations). A comprehensive study comparing the cost effectiveness of all three means of transporting goods to market is presented in Appendix D, Section I. A detailed example reflecting a market distance of 150 miles roundtrip for a buy-back center is presented below.

The following truck costs were used for the buy-back center:

25 ton Hoist Truck	$60,000

Labor: $12.50/hr. including fringe benefits
Fuel: 5 MPG and 300 miles/day (150 miles round trip per load)[7]
Operation: 8 hrs/day and 22 days/month
Amortization: 5 years on $48,000 @ 9% interest
Depreciation on $50,000

TABLE 28

PRIVATE OWNER MONTHLY TRUCK COSTS

Monthly Costs	
Amortization	$ 996
Depreciation	417
Fuel	660
Labor	2,200
Insurance*	300
Registration Fees**	65
Maintenance	450
Total Monthly Cost	$ 5,088

* - 100,000/300,000 BI - 100,000 PD - 250 DED. COMP. & COLLISION
** - Includes vehicle registration, weight, and license fees averaged over life of vehicle.

As an example, for a buy-back center, fixed costs are $1,778 per month and operating costs are calculated to be $4.08 times the tonnage per month (TPM). It is found that 140 TPM will support the operation of a truck owned by a buy-back recycling center.

At this TPM the truck is in use 30 hours per month; this is an efficiency (considering 176 hours/month maximum use) of 17%. Maximum utilization (176 hours/month) requires 810 TPM throughput for the buy-back center.

Based on conversations with a number of recycling centers and debris haulers, a figure of $35 per hour was most often quoted for a 1978 contract hauling rate. If the buy-back center rents or contracts with a local hauler the maximum cost (assuming 176 hours/month transportation time) will be $5,160. The TPM shipped would be 810. A 110 TPM would support the monthly rental of a transport vehicle. In comparing truck purchase versus truck rental, it is determined that around 487 TPM is the point of indifference where truck rental or ownership has the same impact on profit. Below this point, it is advantageous to rent a truck at the $35/hour figure; above this point, it is advantageous to purchase a truck. For lower TPM, therefore, it can be concluded that truck rental is the more economical of the two.

The current lack of transportation services by permitted carriers to haul materials from the recycling center to markets results from many adverse conditions. First, transport requires specialized equipment necessary to hoist storage bins. There are few permitted trucks which have chassis specialized for hoisting these bins; therefore, little transportation of recyclables occurs, given the competition for the vehicle's use by other industries. Second, the minimum rates for the commodities in the PUC tariffs are financially prohibitive for the recycling centers. A permitted carrier would charge for hauling the material to market, as well as the empty return haul. Centers simply cannot afford to pay for this empty haul-back with the bin. Third, recycling centers generally do not own nor can they afford to purchase storage bins. Storage containers, then, if not provided by a broker, are generally makeshift boxes made of wood or steel. If the bin is supplied by the permitted hauler at the time of loading, a difficulty results in transferring the material into the transport bin. This requires much time, as the material transfer is generally not automated. Fourth, many centers have a cash flow problem, which results in marketing of materials in low volumes and tonnages. It is unprofitable however, to use PUC carriers to ship such low volumes.

If the center was able to contract with a for-hire carrier permitted by the PUC, the MRT 2 commodity tariffs would be used. It is assumed that the carrier will include a charge for returning storage bins to the center's location after hauling the load to market; thus, a round trip would be charged. The following analysis is based upon the MRT 2 commodity tariff which is the baseline for negotiating prices for transportation. The following loads were considered: aluminum @ 10 tons per load, newsprint @ 24 tons per load, and glass @ 24 tons per load. The volume of the container is 45 cubic yards. Round trip distance is 150 miles, requiring 4 hours per trip.

The following illustrate costs per commodity trip:

	Rate/ton @ 150 Miles	Dollars Per Trip
Aluminum	$24.77	$248/trip
Newsprint	$11.05	$265
Glass	$ 8.00	$192

The average rate per ton material is calculated to be $11.62/ton. (See determination of PUC rates in Appendix D, Section I.) Ferrous is excluded from the analysis because of its low market value. It was determined that for a buy-back system, 122 TPM will support the cost associated with the PUC minimum tariffs.

Of the three options, truck rental is found to be the most cost effective means of transportation at a distance of 150 miles to market for low TPM.

SECTION 2 - RECYCLING CENTERS

I. Community Drop-off Recycling Centers

Community drop-off recycling centers have been in operation since the late 1960's and at the present time there are approximately 100 centers around the State. Throughput for these centers ranges from five to fifty tons per month.[8]

The type of material accepted by each center is largely determined by the local markets available for that material. In the larger metropolitan areas, centers received the full range of recyclable materials while other centers in less densely populated areas, not having the available markets, rely heavily upon aluminum and newsprint for revenues.

There is no one description of a drop-off recycling center. Each center is unique in staffing, material processing, storage, transportation equipment, and the degree of subsidy (i.e., volunteer help, donated equipment and grants from the various levels of government). A synopsis, therefore, will be provided describing the general method of operation as well as the requirements for labor and equipment. In the analysis of cost, however, a model will be used which minimizes the cost of operation and which generates the maximum revenues for the minimum costs. Commercial accounts are not included in the analysis.

A. Background

The community drop-off recycling center is characterized by a monthly throughput less than fifty tons per month, volunteer help, and donated land and equipment. The degree of donated help, land and equipment impacts heavily on the economic viability of the center. A center may function independently of other recycling operations or it may serve as a satellite for a larger recycling operation.

Facilities are generally unattended; therefore, minimal storage containers are provided for patrons to deposit recyclable material. The material is periodically checked for quality, and when the containers are full, the material is dumped into larger rented or leased transport containers. Upon reaching a maximum load, the container is picked up by a secondary materials broker and an empty container is deposited in its place. The rental of the storage bins and the cost of transporting materials to market may reduce revenues by as much as 50%.[9]

The operators of these smaller community recycling centers are typically service organizations or schools. As such, many of the operational costs are defrayed by donated land, equipment, and labor. There is a problem, however, with the reliability of the labor pool, especially during adverse weather.

Materials processing for these smaller community drop-off centers varies considerably and is dependent on the product specified at the market place. Newspaper will command a higher price if it is in a high density form and easily stored, loaded, transported, and off-loaded. Storing newspaper loose in large 45 cubic yard containers solves the need for easy storage and transportation; however, the material lacks density, and container dumping creates storage problems at the manufacturing level. The market for loose newspaper, therefore, is limited. The banding of stacked papers on 4' x 4' pallets provides a better mechanism for processing newsprint. Pallets of newsprint ready for market are moved with the use of a pallet jack and can be loaded onto a flatbed truck either by liftgate or loading dock. An 18' truck can handle up to 8 pallets per trip with each pallet weighing one ton (64 cubic feet volume of paper).

Glass processing into cullet depends heavily upon the market. Bulk processing consists partially of crushing glass of all colors and dumping into a large container (e.g., 45 cubic yard bin). Minor quality control is performed by removing impurities such as paper and metal rings. Some markets require color separation and the price received is considerably higher, especially for flint or clear glass. Colors are usually stored in small containers to facilitate handling, loading, and transport to market where the materials are weighed. Aluminum and ferrous are generally handled in the same manner.

The monthly cost to the consumer who drops-off recyclables at the nearest community center is calculated at \$0.20 assuming that the average householder generates approximately 35 pounds of recyclable material each month, has a 16 mile per gallon vehicle for which he pays \$0.65 a gallon of gasoline, and travels 5 miles round trip to a local center. In terms of the cost per ton of recycled material for consumer transportation per month, the amount would be \$11.43 for 57 households. While the cost per ton of material may appear significant, especially related to the profit per ton realized by the community drop-off recycling center, the expense is spread out over the community and not upon the individual consumer or recycler. This consumer cost is not included in this analysis. (See Appendix D, Section VI).

B. Analysis Assumptions

As indicated previously, a model will be used for the analysis of cost which minimizes the risk and cost of operation and which maximizes revenues. For cost-effectiveness it may be in the interests of the center to operate in conjunction with a larger processing facility to take advantage of the facility's markets and its possible means of transporting goods to market. This arrangement would also confer benefits to the processing facility because it would be in a better position to establish a long-term contract with buyers, the basis of which is the ability to supply an adequate volume (as well as quality) of material in a particular time frame.

The center would store glass, ferrous, and aluminum in 1.5 cubic yard steel containers with rollers, and newspaper would be stacked. Material processing would include removal of contaminants, partially crushing aluminum and glass, and banding the newsprint on pallets. The material is transported to the larger processing facility, via a rented 12 foot flatbed truck, when a sufficient amount is collected to fully utilize the vehicle's capacity.

The following assumptions were made in the analysis of cost for the community drop-off centers:

1) the site is donated with the exception of a utility shed and fencing,
2) labor for the first ten tons throughput is donated.[11] Parttime help would be hired on the basis of 1½ hours per ton throughput in excess of this amount.[11] Labor will be paid at the rate of $4.07 per hour including fringes,
3) all utilities are donated.

The following table displays the percentages by weight of recyclable material (derived from data supplied by various drop-off centers around the State), and the revenue per ton for such material.

TABLE 29

PERCENTAGE COMPOSITION AND PRICE OF MATERIALS
FOR COMMUNITY DROP-OFF CENTERS

	Percent	Price/Ton
Aluminum	1.1	$340
Newsprint	61.2	15
Glass	25.9	15
Ferrous	11.8	0

The revenue per ton of throughput using the above data, is calculated at $16.80.

C. Analysis Results

A detailed cost breakdown is presented in Appendix D, Section 2-I. The following represents the monthly cost and revenue breakdown of the community drop-off center by volume of throughput.

TPM	Cost/Month	Revenues/Month	Profit/Month	Revenue/Ton
10	$224	$168	$(76)	$(7.60)
20	377	337	(40)	(2.00)
30	462	504	42	1.40
40	598	672	74	1.85
50	711	840	129	2.58

A linear regression analysis on profit given the tonnage throughput yielded a correlation coefficient of 0.991 and a breakeven point of 17.7 tons per month. The following equation can be used to estimate the profit for this particular community drop-off system:

$$\text{Profit/Month} = \text{TPM}\ (5.24) - \$131.40$$

Looking at the average monthly cost over the range of throughputs from 10 to 50 TPM, it is found that labor represents approximately 25% of total costs. This figure, however, may vary significantly depending on the amount of volunteer help.

II. Buy-Back/Processing Recycling Center

With the larger drop-off recycling centers (greater than 50 tons per month), the reality of a more complex system is apparent. Processing of the material into easily manageable volumes of high density is desirable. Such processing requires:

1) processing equipment
2) additional labor to operate equipment and manage volumes of material coming through, and
3) some method of transporting materials to market, usually via broker or manufacturer.

The processing facility may service and accept materials from satellite community depots providing assistance in securing stable markets for the community recycler and providing transportation of materials to market.

A motivational factor which provides incentive to the consumer to recycle its materials is the "buy-back" approach. At the center, materials are purchased at a nominal price below the price at which the facility sells to the manufacturer or broker. The buy-back program may be open to the public and/or to other community centers and material purchase may be limited to one or several types depending, again, on the local market.

A. Background

Buy-back recycling centers are busy during weekends, and often purchases of secondary materials may exceed five tons per day. Materials must be quickly and accurately weighed with a minimum transaction time, otherwise the incentive for the consumer to participate in a buy-back program will be reduced. Recently, there has been a move to automate the purchasing of material and accounting by using a microprocessor-based digital scale, with ticket printout, that either credits an account (which is paid monthly) or issues a check immediately to the customer. Automation will not only reduce purchase time but it will also relieve yard employees and clerical staff for other purposes.

The use of a digital scale which has the ability to set tare weights to zero would greatly assist buy-back centers in purchasing and handling materials.

Unforturately, the use of such scales would subject profit-oriented buy-back centers to operate under public weighmasters requirements (Section 12701(j) of the Business and Professions Code). Under current law only non-profit buy-back programs are exempt from the requirements governing weighmasters. A change in the law to exempt all buy-back programs from the public weighmasters requirements would greatly enhance the statewide recycling effort.

B. Analysis Assumptions

In preparing the cost analysis for buy-back centers, the following assumptions were made:

1) The center is operated for profit thus it must comply with Section 12701(j) of the Business and Professions Code.
2) Labor time for material processing is 45 minutes per ton throughput.
3) Two scales are required; one for aluminum and the other for glass. (Newsprint can be handled on a price per stacked height basis).

C. Analysis Results

A percentage breakdown of materials by weight was calculated using three existing buy-back programs in the State. These figures as well as the price of the material paid to the public (cost per ton), the market price of the material received by the center (revenues per ton), and the difference of these figures (premium per ton) are presented in the table below:[2]

TABLE 30

PERCENT COMPOSITION AND PRICE OF
MATERIALS FOR BUY-BACK

	Percent	Cost/Ton	Revenue/Ton	Premium/Ton
Aluminum	9.0	$340	$640	$300
Newsprint	77.6	15	35	20
Glass	10.2	15	18	3
Ferrous	3.2	0	0	0

Using the above figures, the revenue per ton of throughput is calculated at $42.83.

The following represents the monthly cost and revenue breakdown of the buy-back recycling center by the throughput tonnage of materials. See Appendix D, Section 2-II for details.

TPM	Cost/Month	Revenue/Month	Profit/Month	Profit/Ton
50	$5,463	$ 2,141	$(3,332)	$(66.44)
100	$5,598	$ 4,283	$(1,315)	$(13.15)
200	$5,875	$ 8,565	$ 2,690	$ 13.45
300	$7,177	$12,848	$ 5,671	$ 18.90
400	$7,454	$17,130	$ 9,676	$ 24.19
500	$8,756	$21,413	$12,657	$ 25.31

A linear regression analysis of tonnage on profit gave a correlation coefficient of 0.999 with a breakeven point of 136 tons per month. For this particular system, the following equation obtained from regression analysis can be used to estimate profit per month.

$$\text{Profit} = \text{TPM}\ (35.57) - \$4,845$$

III. Separate Curbside Collection

The separate curbside collection system has met with varying success throughout the State. The majority of these operations have evolved from existing drop-off recycling centers in order to collect increased tonnages of recyclable materials from the consumers residence. Historically, the rate of participation by consumers in these programs averages 20%.[13] A problem common to this method of collection has been to find the most efficient yet least expensive means of collecting materials from the curbside of the consumer. For the most part, however, the state-of-the-art for separate curbside collection systems is too diversified and, quite often, too costly.

A. Background

The separate curbside collection system assumes a variety of forms. One method, for example, employs several auxiliary, small capacity three-wheeled scooters whose maneuverability facilitates pickup in high density residential areas. These vehicles work in conjunction with a large capacity transfer truck. Materials collected from the curbside, which are source separated by the consumer and deposited curbside in separate lots, are loaded into bins of the scooter and are transported to the transfer truck for deposit into large containers. When these containers are full, the truck carries the material to the center where it is off-loaded by hand. This system has considerable cost associated with the increased number and maintenance of collection vehicles plus the additional salary cost of the operators needed for collection. Moreover, the additional time taken by the transfer of the materials from the scooters to the truck adds to the cost of operation.

Another separate collection system involves the use of a flatbed truck chassis which carries six 1.5 cubic yard bins for the collection of newsprint, mixed glass, and aluminum/ferrous cans. The truck follows the equivalent of three garbage collection routes daily for its curbside recycle collection. The advantage of having many bins is in the flexibility of handling an overflow of any one material (usually newspaper). At the processing center, the bins are off-loaded by a rotating head forklift into larger 45 cubic yard bins or the material is dumped and fed through the material processing system. This system, however, is not without drawbacks, most notably the wear on the collection vehicle and a lower fuel efficiency. For this vehicle type, fuel consumption during collection has averaged five (5) miles per gallon. In addition, the payload is small, usually requiring two trips from the collection route. As a result, costs for labor and fuel increase.

The last system to be described consists of a pickup truck and a gooseneck trailer. Newspapers are stacked into the bed of the pickup, while glass and cans are deposited into bins on the trailer. The trailer carries four bins and each bin has a capacity of three cubic yards. The payload for this collection system is greater than those mentioned above, and thus there is a reduction in trips to and from the collection route, as well as a reduction in fuel and labor costs.

With some variation, the separate curbside collection programs around the State are described by one of the above systems. Variations include the frequency of collection (weekly, bi-monthly, monthly), staffing, and the time allocated for collecting material. Unfortunately, the element common to most curbside systems is high operational and equipment cost. Losses in some cases have exceeded $40.00 per ton of material processed. Traditionally, the curbside collection system has only been able to maintain itself financially through Federal, State, and local subsidies.

B. Analysis Assumptions

A detailed analysis of California's curbside collection systems could not be accomplished for a number of reasons. First, it was discovered that wide variation in staffing, equipment, and related costs exists; and, as a consequence, costs reflecting the typical operation could not be determined. Second, data were lacking on the breakdown of component costs. Finally, markets and transportation costs of material to market varied from region to region.

In view of the above variables and lack of tangible information, an analysis of a theoretical composite system will be presented with component cost information supplied when available from data of the existing systems. The composite will illustrate the minimum separate curbside collection system necessary for various levels of throughput. For increasing TPM, site characteristics and processing equipment are identical, with variable costs increasing directly.

Processing time has been estimated at one hour for each ton of material collected. Furthermore, for every 100 TPM throughput, one collection vehicle (pickup truck, trailer and six bins) is necessary. This assumes that 4.5 tons per day are collected per vehicle.

C. Analysis Results

Based on data supplied from five existing separate curbside collection systems, the percentage breakdown of materials by weight and the price received per ton of material is as follows:

TABLE 31

PERCENTAGE COMPOSITION AND PRICE OF MATERIALS FOR SEPARATE CURBSIDE COLLECTION SYSTEMS

	Percent	Price/Ton
Aluminum	1.3	$640
Newsprint	54.8	35
Glass	34.8	18
Ferrous	9.1	0

The following is a summary of the analysis of cost for separate curbside collection systems for 100 to 600 TPM. Details are furnished in Appendix D, Section 2-III.

TPM	Cost/Month	Revenue/Month	Profit/Month	Profit/Ton
100	$ 6,987	$ 3,376	$(3,611)	$(36.11)
200	$ 9,942	$ 6,653	$(3,289)	$(16.45)
300	$11,877	$10,129	$(1,748)	$(5.83)
400	$14,838	$13,506	$(1,332)	$(3.33)
500	$17,490	$16,882	$(608)	$(1.22)
600	$20,456	$20,258	$(198)	$(0.33)

The breakeven point has been estimated at 589 TPM with linear regression analysis. By inspection, however, it can be seen that the breakeven point is just over 600 TPM. The following equation can be used to estimate the profit of tonnages in excess of or different than those illustrated.

Profit/Month = TPM (7.30) - $4,354   Correlation = 0.979

The addition of an aluminum buy-back program to the above curbside systems significantly improves its profitability. The following analysis illustrates the economic impact of buying back aluminum equivalent to 9% of total throughput weight. It is assumed that curbside collection of aluminum is negligible and thus will be omitted as a revenue source.

TPM	Cost/Month	Revenue/Month	Profit/Month	Profit/Ton
100	$ 7,071	$ 5,046	$(2,025)	$(20.25)
200	$10,051	$10,091	$ 40	$ 0.20
300	$12,011	$15,136	$ 3,125	$ 10.42
400	$14,997	$20,181	$ 5,184	$ 12.96
500	$17,624	$25,227	$ 7,553	$ 15.11
600	$20,665	$30,272	$ 9,607	$ 16.01

The above analysis indicates that with the addition of an aluminum buy-back program the breakeven point drops to 184 TPM, a reduction of 69%. Again, to estimate tonnages in excess or different than those illustrated, the following equation may be used.

Profit/Month = TPM (23.65) - $4,362   Correlation = 0.998

The percentage breakdown of materials by weight and the price received per ton of material for this system is as follows:

TABLE 32

PERCENTAGE COMPOSITION AND PRICE OF MATERIALS FOR SEPARATE CURBSIDE COLLECTION SYSTEM WITH ALUMINUM BUY-BACK

	Percent	Price
Aluminum	9.0	$300
Newsprint	50.5	35
Glass	32.1	18
Ferrous	8.4	0

IV. Integrated Curbside Collection System

A. Background

The integrated curbside collection system, one where employees of a residential waste removal service pick up recyclable materials in addition to residential garbage, has had little success in California. Currently no integrated system is operated to collect more than one recyclable material, and the few that exist collect only newspapers which are loaded onto a rack retrofitted to the chassis of the waste collection vehicle. In 1978 a franchised garbage collector for a mid-sized city in the State initiated an integrated system to collect mixed glass, newsprint, and mixed cans. The system used 55 gallon steel drums which were strapped to the sides of the waste removal vehicle for the segregated collection of these materials. The containers, however, met with employee disapproval because of the extra time involved and the difficulty in handling and unloading. The project was abandoned after five months due largely to the use of this storage equipment, and the separate curbside collection system, which had been operating with some success, was fully reinstated.

B. Assumptions

Inasmuch as commercial integrated collection vehicles are not produced, it is difficult to express the cost of an original design vehicle or the cost of modifying an existing collection vehicle chassis. Nevertheless, such a vehicle would be more expensive than those currently produced for residential waste removal only. Since these costs are indeterminate and therefore cannot be characterized, this analysis will assume the existance of an integrated collection vehicle and will address only the cost of processing the collected material. Material processing costs are assumed to be equal to costs incurred under a separate curbside collection system. In addition, increased labor costs due to the added time required to collect recyclable materials will be assumed to be negligible.

It is further assumed that the facility needed to process the material obtained will be located adjacent to the existing yard and that additional office space will not be necessary for program administration. Additional labor, however, will be included for clerical staff, management and yard personnel. Percentages by weight composition are considered identical to those of the Separate Curbside Collection system. (See Tables 37 and 38).

C. Analysis Results

The following is a summary of the cost analysis for integrated curbside collection systems of 100 to 600 TPM. Included under revenue is an amount for tipping fee cost reduction equal to $3.00 per ton (the average tipping fee in California in 1978). See Appendix D, Section 2-IV for details.

TPM	Cost/Month	Revenue/Month	Profit/Month	Profit/Ton
100	$ 5,221	$ 3,675	$(1,546)	$(15.46)
200	$ 6,517	$ 7,353	$ 836	$ 4.18
300	$ 6,790	$11,029	$ 4,256	$ 14.13
400	$ 8,090	$14,706	$ 6,616	$ 16.54
500	$ 9,081	$18,382	$ 9,301	$ 18.60
600	$10,387	$22,058	$11,671	$ 19.45

The breakeven point has been estimated at 157 TPM with linear regression analysis. The following equation can be used to estimate the profit for tonnages in excess of or different than those illustrated:

Profit/Month = TPM (26.81) - $4,199 Correlation = 0.999

The addition of an aluminum buy-back program to the above integrated system significantly improves its profitability. The following analysis illustrates the economic impact of buying aluminum equivalent to 9% of the total throughput weight. It will be assumed that curbside collection of aluminum will be negligible and thus will be omitted as a revenue source.

TPM	Cost/Month	Revenue/Month	Profit/Month	Profit/Ton
100	$ 5,305	$ 5,346	$ 41	$ 0.41
200	$ 6,626	$10,692	$ 4,066	$20.33
300	$ 6,924	$16,036	$ 9,112	$30.37
400	$ 8,229	$21,381	$13,152	$32.88
500	$ 9,265	$26,727	$17,464	$34.92
600	$10,596	$32,072	$21,476	$35.79

The addition of an aluminum buy-back program, lowers the breakeven point to 97 TPM, a reduction of 38%. The following equation was obtained by regression analysis:

Profit/Month = TPM (43.26) - $4,255 Correlation = 0.999

The percentage breakdown of materials is the same as the breakdown for the Separate Curbside Collection System with Aluminum buy-back. Prices are also identical (See Table 38).

V. Front-End/High Technology Recovery Systems

A. Background

As of this writing, there are no commercial front-end systems in operation in the State which produce RDF and separated recovered materials (i.e. cullet, ferrous, aluminum, etc.). Likewise, no facility exists which produces either process steam or electricity from the combustion of RDF. There are two companies in the State which produce RDF for experimental purposes on a spot production basis. An experiment was conducted in Southern California to produce separated refuse derived secondary material - specifically, aluminum, ferrous, and glass cullet - and a fluff RDF which was flash pyrolyzed to a heavy oil suitable for burning in a local utility boiler. The plant is currently shut down because of extensive equipment problems associated with the pyrolyzer. The front-end system demonstrated the technological feasibility of separating materials from refuse; however, because of a lack of long-term markets for the derived materials, operation of the front-end system was curtailed.

The Ames Solid Wastes Recovery system was used in the energy analysis section of this report; it is unsuitable, however, for analysis of cost for several reasons. First, the Ames facility is a site-specific plant which has undergone many costly design and operational modifications, which in turn have significantly altered original cost projections. Adjusting the costs data, therefore, is unrealistic and would prove misleading. Second, although the Ames facility produces refuse derived secondary materials and RDF, the RDF is used in a retrofit coal fired boiler which currently burns a mix of RDF and coal. Since California does not have coal-fired boilers, it would be improper to use the retrofit cost data.

B. System Used For Analysis

Other plants around the United States in various states of operation and construction could not be used for this cost analysis because of site-specific variations and uniqueness of equipment given the processing technique. It was therefore decided to illustrate the analysis of cost for a capital-intensive resource recovery system by evaluating two SB 1855 feasibility studies funded by the Resources Recovery Preconstruction Activity Fund. Estimated cost data was used to evaluate the cost of converting RDF to electricity by plants located in San Diego and San Francisco. The studies included estimated construction and operating costs and revenues for the solid waste resource recovery and energy conversion facilities.

The San Diego facility was designed to handle 373,000 tons per year of solid waste. The facility will recover ferrous scrap and RDF, and produce electricity as one of the proposed alternates. The resource recovery system consists of two processing lines. The solid waste passes through a shredder to reduce its size, then through an air classifier. The overflow or light material from the air classifier is defined as RDF. The underflow, or heavy material from the air classifier, is conveyed through a primary and secondary magnet separating ferrous scrap from the shredded residue. The shredded residue is trucked to a landfill. The steam and electric generating system contains two boilers (200,000 pounds per hour) and two 30 MW turbines. The system will produce 25.7 MW.[14]

The San Francisco facility was designed to handle 492,750 tons per year of solid waste. The facility will recover ferrous and aluminum scrap, RDF, and produce electricity. The resource recovery system contains two parallel process lines. The solid waste enters the first trommel, where items can be removed that can create hazardous mechanical or maintenance problems in the shredding equipment. Rejected material flowing through the first trommel receives a visual inspection as it is conveyed to Trommel 2. Rejected material will be landfilled. Underflow from the first trommel is shredded and conveyed to Trommel 2. Two tandem sorting zones are incorporated in Trommel 2. The first zone removes sand and glass. Material removed in the second zone is air separated. The heavy material from the air separator is separated into three streams; sand and glass, ferrous and aluminum. The light material from the air separator is combined with material passing through Trommel 2 and conveyed to Trommel 3. The underflow from Trommel 3 is RDF. Material passing through Trommel 3 is recycled to the fine shredder. The steam and electric generation system contains three boilers (one for standby) and two 35 MW turbo-generators. The system will produce 32 MW.[15]

It should be clearly understood that the data presented for the San Francisco and San Diego projects is site specific and therefore serves only for purposes of illustration.

C. Cost Analysis Results

The estimated costs for the San Diego[16] and San Francisco[17] facilities were adjusted to 1978 dollars. A comparison of facility costs is shown in Table 33. San Francisco's building and rolling stock costs are lower because a transfer station is located at the site. Estimated revenues and expenses are indicated in Table 34. No revenue was indicated for ferrous scrap because there was no market for that scrap in 1978. San Francisco power sales are lower than San Diego because electricity produced from hydro power as well as fossil fuel is available in the Bay Area.

TABLE 33

FACILITY COST SUMMARY

(1978 Dollars)

Items	San Diego	San Francisco
Site Work	$ 1,232,000	$ 6,695,000
Buildings and RDF Storage	7,213,000	2,720,000
Equipment	5728,000	6,480,000
Rolling Stock	618,000	1)
Steam Generation	24,920,000	29,697,000
Power Generation	7,961,000	6,078,000
Administration	4,568,000	7,300,000
Contingencies	4,885,000	3,030,000
Sub Total	$57,125,000	$62,000,000.
Financing Cost (30%) 2)	17,138,000	18,600,000
Total	$74,263,000	$80,600,000

Notes:
1) San Francisco will use existing tipping floor, building, and rolling stock at transfer station.

2) Used 30 percent average financing costs. Includes: Bond discount (2.5% Bond issue), capitalized interest during construction (7%-2.5 yrs. capitalized principal and interest (0.09 times the bond issue), start-up costs (6 months of estimated O & M costs), minus the interest earned on principal interest, the start-up costs, and first year principal and interest.

TABLE 34

REVENUE/EXPENSE COMPARISON

(1978 Dollars)

Revenues/Costs	San Diego	San Francisco
Expenses		
Labor	$ 1,175,930	$ 1,626,,180
Disposal	1)	1,616,060
Property Tax	1)	499,090
Insurance	1)	249,550
Operating and Maintenance	2,823,730	1,016,010
Administration	176,390	579,910
Income Taxes	N/A	550,750
Data Processing, Security	N/A	249,550
Amortized Capital (7% for 20 yrs.)	7,009,890	7,608,070
Annual Cost	$11,188,940	$13,995,170
Revenue		
Power Sales	$ 4,073,700	$ 7,080,550
Aluminum Scrap	N/A	1,098,000
Ferrous Scrap	3)	3)
Total Revenue	$ 4,073,700	$ 8,178,500
Net Cost ($/ton)[4]	$19.10	$11.80

Notes:
1) Cost included under Operating and Maintenance.
2) Power sales based on 25 miles per kilowatt hour.
3) No ferrous scrap market in 1978.
4) Net cost does not include tipping fee.

SECTION 3 - CONCLUSIONS

In regards to the cost of transporting materials to market, it can be concluded that:

1) The greater distance to the market and the greater the TPM, vehicle ownership appears to be the most cost effective method of material transport. This is to be expected because fixed costs are spread out over a larger base.

2) For lower TPM and shorter distances to market, vehicle rental at a rate of $35 per hour appears to be the least expensive method of shipping goods to market.

3) Minimum rate tariffs established by the PUC for transportation appear to be the least likely used. In no case could PUC transporters be used on a profitable basis. For lower TPM, however (i.e.: below 100 TPM), all systems examined produced no net profit; PUC produced the least amount of loss at distances of 400 miles and over from market.

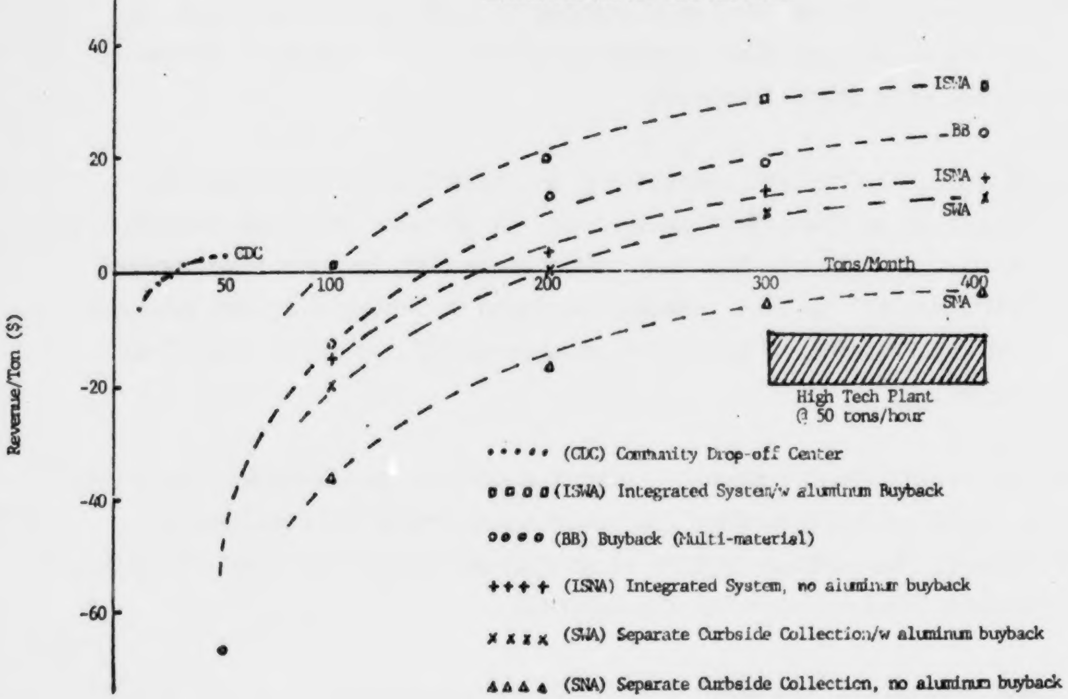
Given the standardized composite recycling centers as previously described and the market price structure and operational costs both defined in 1978 dollars, the various type of recycling centers become cost effective at a certain level of material throughput.

For lower throughput tonnages (20-50 TPM), the Community Drop-off Center is the only cost effective system. With a higher TPM, a buy-back option of some materials at restricted hours could be instituted; but, the principal monthly expense, labor, will have to be offset by the revenues of the buy-back program. Labor above 10 TPM will be paid the going rate at approximately 1.5 hours per ton of material deposited.

Centers which are able to process and market materials are ranked for cost effectiveness with over 100 TPM throughput: (See Figure 10).

1) Integrated curbside collection with aluminum buy-back.
2) Multi-material buy-back.
3) Integrated curbside without aluminum buy-back.
4) Separate curbside collection with aluminum buy-back.
5) Separate curbside collection without aluminum buy-back.

Fig 10 FINANCIAL COMPARISON OF RECYCLING SYSTEMS
REVENUE PER TON vs. TONS PER MONTH



An aluminum buy-back program in any system contributes significantly to the economic viability of a resource recovery operation. For example, separate curbside collection is not profitable until tonnages in excess of 589 TPM are obtained. With the introduction of an aluminum buy-back system, the breakeven point is lowered to 184, or by a reduction of 69%. It is further concluded that the majority of volume and weight will reside with the processing of newsprint. Also, glass will produce the least revenue next to the absense of revenue from recycling ferrous materials.

Based upon the two proposed high-technology systems for California, it appears that there will be a net loss per ton of between $10 to $20. Although a considerable amount of material will be recycled and energy produced from the burning of RDF, operational expenses will have to be offset by either a tipping fee or government subsidy. This system may be quite economically acceptable in areas with existing comparable solid waste disposal charges.

REFERENCES-CHAPTER II

1. California Public Utilities Commission, "A Report to the California Legislature in Response to Assembly Concurrent Resolution No. 48", Transportation Division, June 1979, Page 14.

2. California Public Utilities Code, MRT-2, Section 1, Item 32-k.

3. Inquiries into rental rates around the State.

4. California Public Utilities Commission, op. cit., Pages 14-15.

5. Ibid, Page 16.

6. Ibid, Pages 12-14, 15-16.

7. Environmental Protection Agency, Salvage Markets for Materials in Solid Wastes, SW-29C, 1972, Page 11.

8. Survey of SB 650 Proposals.

9. Ibid.

10. See Appendix D, Section 1-VI.

11. Portland Recycling Team, Resource Conservation Through Citizen Involvement in Waste Management, August 1975, Page 51 (Analysis done on Table 8).

12. 1978 Average, quoted prices from around State.

13. Survey of curbside collection participation rates from programs around the State.

14. Stanton, Stockwell/Henningson, Durham & Richardson, Southern California Urban Resource Recovery Project, Phase II-A San Diego/Navy Energy and Materials Recovery Feasibility Report, October 1977, Pages 6-28 to 6-33.

15. San Francisco Resource Conversion Center, Progress Report No. 1, Concept Design Study, September 1978, Pages 80-94.

16. Stanton, op. cit., Pages 6-48 to 6-54, Appendix C 11-13.

17. SB 650 Grant Proposal.

CHAPTER THREE
IDENTIFICATION OF SECONDARY MATERIALS MARKET CAPACITY AND VARIABLES AFFECTING THAT CAPACITY

I. Introduction

Marketing, the bringing together of buyers and sellers, is a vital component of effective resource recovery efforts. Without an effective marketing program, a resource recovery effort is doomed to ineffective utilization of recovered materials and inadequate revenues to support the recovery program. Although the rationale for resource recovery includes the conservation of natural resources and the reduction of energy requirements for product manufacture, it must be recognized that there is also a need to provide revenues for resource recovery operations. Marketing provides the mechanism for generating those revenues and placing the recovered materials back into the materials utilization process.

Marketing is also the means by which the users of recovered materials are able to define and obtain a supply. Since most recovered materials are sold to product manufacturers and others in the industrial sector, it is useful and important to be aware of the behavioral differences in the purchasing decisions between industrial buyers and other consumers.

The following discussion serves to illustrate some of the characteristics of this industrial buyers group.

In comparison to the general consumer, industrial buyers do not purchase to satisfy personal needs, but rather to satisfy the objectives of the organization they represent. Industrial goods are bought to produce other goods to be sold at a profit. The products that are produced must have guarantees of performance (quality and supply) so as to be competitive in the industrial goods marketplace. As a result, the performance of industrial products in the industrial sector is the most important consideration to a buyer. Additionally,

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industrial buyers are better trained to evaluate the functional aspects of the products they purchase than the general consumer. There are an estimated 4 to 12 people involved in each industrial buying decision.

Recycling industry buyers differ in buying habits from conventional industrial buyers in general. One of the first observations made about all recycled products in general was that there was a remarkable uniformity of purchase price per unit among industrial end-users in a particular industry, regardless of the number of units a buyer was willing to buy. This was not the exception, but rather the rule, for virtually all the products investigated.

According to economic theories on supply and demand, one would expect to observe changes in prices for differing volumes of the same quality product. In fact, according to the historical economic and free marketing practices, if the recovered product was fulfilling a real demand or need, there should have been active and competitive pricing among prospective buyers for a valuable product. There is no evidence of this happening in the recycled materials market.

In an effort to explain this phenomenon an analysis of the buying practices and market structures of recycling industries was undertaken. It was found, for example, that economics defines "administered" prices characteristic of "oligopolistic markets". Oligopolistic markets are those where prices are controlled to some degree, rather than allowed to float at free market conditions.

Typically, an oligopolist has few competitors and produces a product that has little or no real differences between it and a competitor's product. It was observed that buyers in the California resource recovery markets, who in turn become sellers, in fact produce products having little or no differences (e.g., what is the difference in the aluminum stock produced by Alcoa or Reynolds Aluminum Companies?). The same is true for recovered products and this is the reason for the lack of competitive pricing.

This kind of economic structure occurs because it costs millions of dollars to build an integrated aluminum plant. The tremendous cost in producing this product alone is enough to keep out many would-be competitors. However, if aluminum could be produced as easily as agricultural products, there would be many more aluminum companies in the United States, and existing aluminum companies would have to deal with much more competition.

Another factor to consider with very large companies is "vertical integration". This occurs when a company owns its source of raw materials as well as its refining and fabricating plants (e.g., glass companies). Large sums of money are tied up in capital equipment for processing the present form of raw material. If a recovered product is substituted for a raw material which a vertically integrated company currently mines, mining equipment would be idle, constituting a tremendous expense and waste of resources to the company.

For this reason alone it is doubtful if recovery products in general will ever constitute a major part of an existing company's overall production. Additionally, one of the many reasons that a company vertically integrates is to reduce its dependence on a raw materials supplier. If vertically integrated companies were to purchase significant quantities of recovered products as raw materials, they would again be dependent upon a supplier. Most of these companies would have difficulty in aligning such a change in buying practices with their existing policy goals.

In summary, sound marketing planning for resource recovery requires answers to several questions. What does the market (industry) need? Can those needs be satisfied with a recovered product? Who are the key (industrial) decision makers? Under what conditions will the market (industry) purchase? Since the answers to these questions are dependent upon purchasing behavior in the industrial marketplace, they can only be obtained through a thorough understanding of the behavior which eventually leads to either the purchase decision or letters of intent to purchase.

II. Recycled Products Markets Investigation

For the purposes of this report the number of products to be investigated has been limited to ferrous metals, aluminum, glass containers, and newspaper.

The results of a market survey on secondary materials completed for the State Solid Waste Management Board by Kenneth L. Barasch and Associates in August, 1978[1] are presented for these four materials. A description of the methodology has been extracted from the report and is as follows:

In an effort to identify potential buyers of the materials recoverable from the North Counties area, a census of "possible" buyers in the State of California was conducted (with emphasis on finding buyers in the 9-county San Francisco Bay area). Rather than conduct a survey based on a small sample of the overall market and then try to extrapolate the findings, an attempt was made to contact all past, current, and prospective purchasers of the selected materials.

Companies and plants from every Standard Industrial Classification (SIC) with current, potential, and/or even remote chances of using the recovered materials were contacted. Names and addresses were obtained from a wide variety of sources. All potential material users were contacted via telephone and screened as to current and future use and purchase of the recovered materials. A copy of the screening form is presented in Appendix E.

To each respondent indicating current, future, or potential use of any recovered material, a questionnaire and study and material description were mailed with a postage-paid return envelope. The return envelopes were pre-coded with the SIC (industry) number in the corner to insure accurate identification of each respondent.

Each respondent not returning his questionnaire within two weeks was telephoned to encourage a speedy response and/or to answer the questionnaire over the telephone.

The survey was quite discriminating in separating would-be buyers from non-buyers. Due to the in-depth screening prior to sending a questionnaire, and the use of an extremely long and confidential questionnaire, it appears that those who did express a willingness to buy are indeed solid prospects. In essence, this survey was barely one step short of asking for an order.

Table 35 presents a summary of the calls made, questionnaires sent, and questionnaires returned for each of the 8 materials studied. Overall, 5,548 screening contacts were made, resulting in 1,087 questionnaires being mailed, and 205 completed surveys (19 percent). This completion rate is extremely high in light of the in-depth information requested, the length of the questionnaire, the need to complete two or more questionnaires in many cases, and the near-commitment to buy on the part of the respondent.

TABLE 35

SUMMARY OF CALLS MADE/QUESTIONNAIRES SENT/RECEIVED

MATERIAL	# of SIC Industries Contacted	Total # Locations Contacted (Screened) By Phone	Total Questionnaires Mailed (Potential Buyers)	Total Questionnaires Returned	Return %
Ferrous	16	742	261	49	19%
Aluminum beverage cans	14	768	246	53	22
Mixed non-ferrous	8	457	66	8	12
Hand-sorted cullet	13	534	40	11	28
Mixed cullet glass	12	453	15	6	40
Mixed waste paper	23	852	137	18	13
Old newspaper	24	860	154	24	16
Old corrugated	26	882	168	38	23
TOTALS		5,548	1,087	207	19%

A. Ferrous Metals

The major advantage of scrap iron and steel over other recoverable materials is its ease of separation from mixed municipal wastes. However, there is presently no way to differentiate between the various grades of scrap without hand separation, necessary for quality grade scrap at the highest possible price.

Markets

In California the markets for ferrous scrap include foreign trading companies, domestic dealers, brokers and end users. The choice of which markets to select is dependent upon market demand at that time, the specific kind and quality of scrap and whether a given resource recovery facility is able to economically upgrade the quality of ferrous scrap to meet those demands.

One of the fastest growing markets for purchased steel scrap is the export market. In 1970, the United States exported 24 percent of its purchased steel. Japan has demanded the largest national market share at 48.8 percent. In 1974, San Francisco exported over 673,000 tons of ferrous scrap, of which Japan purchased over 52 percent. The approximate price for the scrap exported was about $100/ton and was reported to have included shipping costs. Data are not available, however, on the shipping costs. The subtraction of shipping costs from selling price would allow direct comparison to the San Francisco domestic market.

Domestic dealers in ferrous scrap can be separated into three general categories depending upon the ferrous scrap and use. Those uses are copper precipitation market (including detinners and end users), the steel remelt market and the secondary materials dealers (whose use may include remelt, copper precipitate, and export markets).

The copper precipitation markets have three avenues by which ferrous scrap may reach the copper industry. One of the channels by which ferrous scrap reaches the copper industry is by the detinners. In the United States, 60 percent of the detinned steel goes to the copper industry. The tin is a byproduct removed when preparing steel cans for use in either the steel industry or the copper industry. Tin is a valuable material, but despite the high value of tin, its recovery is an uneconomical process at this time.

The Barasch survey[1] of recovered ferrous found some markets for steel cans. The findings are as follows:

1. Respondents' Past Experience With Recovered Ferrous

   a. Thirty-one percent of survey respondents were purchasers of some quantity of ferrous.
   b. Four of the 6 SIC's noted past purchase or use of recovered ferrous, including copper ore mines (SIC 1021), blast furnaces and steel mills (SIC 3312), gray iron foundries (SIC 3321), and scrap dealers (SIC 5093).
   c. Of the 14 purchasers of ferrous, 4 indicated that they did not deal with shredded tin cans. Those in the copper industry indicated the need for clean and detinned cans.
   d. Three manufacturers noted that they produce an average of 640 tons of recyclable ferrous in-house per year.
   e. In the past 12 months, 14 respondents indicated they had purchased a total of 105,550 tons of the described material, or an average of 7,254 tons per company.
   f. The respondents paid an average price ranging between $40 and $66 per ton, with those in the 9-county area with the lower average.
   g. The most prevalent sources from which respondents purchased ferrous were: scrap dealers (53 percent); dealer-processors or the public (47 percent); and landfills and junkmen (33 percent).

i. Even though 53 percent of the respondents feel they have no problems with their current supplier or the material itself, 27 percent complained about contamination in the material.

2. Willingness to Buy Described Tin Cans & Light Gauge Steel

   a. Twenty-five percent of the respondents said they would definitely buy the product. Eight percent said they would consider buying.
   b. Most of the respondents not interested in buying the described material cited the composition of the material itself as the major reason for non-interest.
   c. Scrap dealers appear to be a good channel to reach other industries, such as exporters. Seventy-five percent of the scrap dealers responding sell to exporters and to steel mills, as well as to a number of other industries.

3. Quantities Desired for Purchase

   a. Respondents expressed interest in purchasing 117,150 tons (this figure does not include two who said they would buy an unlimited amount). This total included 29,250 tons in the 9-county Bay Area, as well as 59,000 tons to the copper industry.
   b. It would not be possible to sell the entire available supply of the described product in the 9-county area.
   c. The average shipment was 228 tons. This represented 52 percent of the typical company's needs for the product.

4. Advantages, Disadvantages, Changes Needed in Described Tin Cans and Light Gauge Steel

   a. The price is perceived as the major advantage of the described product, mentioned by 28 percent of the respondents. Another 24 percent felt that the readily available supply would be a major advantage.

b. The major disadvantages were impurities in the described material, including tin (44 percent), as well as the loss that would occur in melting the material down (8 percent).

c. Forty-five percent of the respondents recommended some changes in the physical makeup of the described product. Twenty-eight percent recommended changes in the physical content, eight percent in packaging, and four percent in delivery specifications.

5. Current/Future Price Expectations

a. Price for the described material was estimated to be $44 per ton today and $55 in 2 to 3 years. Several respondents declined to divulge prices today or for the future, perhaps because of the highly fluctuating nature of the prices.

6. Contractual Requirements Desired

a. Sixty-seven percent of those who have bought the product in the past have bought on an as needed basis, with the other third buying on a contractual basis.

b. Primary guarantees requested before negotiations to purchase could take place centered around tonnage and quantity guarantees (36 percent), quality guarantees/chemical content (32 percent), and price (28 percent).

c. Three-quarters of the respondents indicated a willingness to enter into some contractual arrangement, with a 2-5 year time period being the most common (32 percent).

d. Forty percent of respondents would be at all likely to accept a floor price contract, while only 24 percent would be at all likely to accept a "take or pay" contract.

e. Sixty-four percent of the respondents either requested no specific discounts or said they definitely did not want discounts, while most of those who did want discounts would prefer a cash or a cash/quality discount.

7. Preferences Toward Type/Source of Supplier

a. Fifty-four percent of respondents would prefer dealing with a recovery plant which was completely private enterprise. Thirty-two percent had no preference.

b. Forty-four percent of respondents want no government involvement. Eight percent felt there should be fewer government restrictions, and another 12 percent felt that general encouragement should be given to the industry through low-cost, long-term loans facilitating the establishment of viable systems or promoting lower railroad rates.

c. The most preferred source from which respondents would like to buy are dealer-processors (64 percent), followed by scrap dealers (56 percent).

d. The most frequently mentioned sources for obtaining availability and prices for tin cans and light gauge steel were dealers (16 percent) and metropolitan refuse departments (eight percent).

Developments and Projections

Bethlehem Steel Corporation in October of 1974 announced that new developments allow the use of "tin-free" Blackplate steel in the manufacture of beer and soft drink cans. Mid-West Research Institute projects that use of the presently used tin-free steel (chrome coated) will decline after 1975, as industry converts to blackplate. By 1980, industry will have increased its use of blackplate to 35 percent of all steel cans produced. It is expected that tin-plated steel cans will be completely eliminated from the beverage markets by 1990. It is also estimated that tin-plated steel will continue to be the preferred metal by the food industry.

Conclusion

From the information available, it appears that the best immediate market for refuse-derived scrap in California would be either the secondary scrap dealers or the steel can processors for the copper mines. One dealer in each market has indicated that he has the capacity to absorb all the refuse-derived ferrous scrap that the Bay Area could produce. The prices tendered for ferrous scrap in these markets range from $44 per ton today to $55 per ton in 2-3 years. It should be clearly understood that the above price does not apply to bi-metal containers (steel cans containing aluminum closures). Currently there is no market for the bi-metal container. (Please see Chapter 1, Section 5 for a discussion on ferrous scraps and containers).

B. Aluminum

Organizations contemplating resource recovery activities have been investigating the possibilities of substituting secondary aluminum (discarded aluminum products) for primary aluminum derived from aluminum ores (bauxite). Like ferrous metal, secondary scrap aluminum is known as home scrap and purchased scrap. Purchased scrap is further categorized into prompt and obsolete scrap. The largest single constituent of the discarded secondary aluminum fraction includes aluminum cans, foils, trays and packaging. Aluminum containers and packaging grew at a rate of 15.7 percent per year between the years 1960 and 1969.

Markets

In the San Francisco Bay area, four aluminum markets are possible outlets for secondary aluminum scrap. These markets are the primary aluminum producers, secondary smelters, scrap dealers and exporters.

Of the three primary aluminum producing companies, only two operate recycling programs in the Bay Area. The price is generally fixed at about one-half cent per can or $0.17 per pound or $340 per ton. The prices generally range between 48 percent to 60 percent of the 99.5 percent pure aluminum ingot price at $0.41

per pound. All three primary aluminum companies essentially offer the same price for secondary scrap aluminum.

The secondary smelters purchase the majority of aluminum scrap (not including beverage cans) generated in the United States. In the Bay Area there are two aluminum smelters. The combined capacity of this market to absorb scrap aluminum is about 4,500 tons per year. The price is generally somewhat higher than the primary markets.

In the scrap dealer market it was found that these dealers sell to the other three aluminum markets. Therefore, their prices and demand for aluminum are derived from the end user; thus independent resource recovery recycling facilities can expect to get lower prices here than from the end user.

The export markets for scrap aluminum indicate that about 95 percent of all United States aluminum scrap exports leave from the ports of Los Angeles and San Francisco. It is interesting to note that 72 percent of the aluminum scrap exported from San Francisco Bay area was destined for the Republic of China (Taiwan) at a price of $169 per ton. At the same time, Japan purchased the remaining 28 percent at four times the price Taiwan paid, $646 per ton. The reason for this disparity is not exactly clear. For example, the data do not indicate whether the price of shipping was included in the price for Japan or excluded in the price for Taiwan.

The Barasch survey[1] of aluminum beverage cans indicated larger markets exist for aluminum cans. The findings from the survey are as follows:

1. Respondents' Past Experience With Aluminum Beverage Cans

   a. Over 80 percent of the survey's respondents were purchasers of some quality of aluminum beverage cans.

b. Only 4 SIC's noted past purchase or use of aluminum beverage cans: Primary aluminum manufacturers (SIC 3334), secondary metals (SIC 3341), metal can manufacturers (SIC 3341), and scrap dealers (SIC 5093).

c. Of the 44 purchasers of aluminum beverage cans responding to this survey, 32 percent bought cans as described, 17 percent have bought from the public and recycling drives, 17 percent have bought shredded cans, 12 percent crushed, 12 percent baled, and 10 percent briquetted.

d. Three manufacturers noted that they produce an average of 7,433 tons of recyclable aluminum can in-house per year.

e. In the past 12 months, 33 respondents purchased 15,233 tons of aluminum beverage cans, an average of 462 tons per company.

f. The price per ton paid for aluminum beverage cans in the past 12 months ranged from a low monthly average of $378 to a high monthly average of $458.

g. The most common sources from which respondents purchased aluminum beverage cans were direct from the public (62 percent of the buyers using this source), from scrap dealers (48 percent), and scavengers or junkmen (45 percent).

h. The original source of the typical purchase of aluminum beverage cans averaged 33 miles from the buyer's facility.

i. Although 54 percent of the respondents feel that they have no problems with their current supplier or the cans themselves, 19 percent complained about steel, iron, tin and bimetal cans in general that are mixed in, and 16 percent complained about dirt, sand, plastics, and other contaminants.

2. Willingness to Buy Described Aluminum Beverage Cans

a. Fifty-eight percent of the respondents said they would definitely buy, plus 10 percent said they would consider buying the described cans. Where Elrick & Lavidge[3] identified

5 manufacturers willing to buy, the current study located 2 (one primary and one secondary producer). Several other producers simply did not have the time or were completely unwilling to participate. However, these remain significant markets. Elrick & Lavidge noted that the producer market represents 6 times the potential of dealers and exporters, and that future research efforts should ignore the latter groups. However, the current survey shows that when asked to make a firm commitment, the producers note that they cannot use materials with the contamination level given, and would prefer dealing through scrap dealers. So, unless there is considerable change in operating philosophy on the part of producers, dealers will probably be the primary customer of the proposed recovery facility. (Aluminum foundries do not get involved in recovery of cans.)

b. Those respondents not interested in buying the described cans felt freight costs and weight to storage ratios were insurmountable problems.

c. The single largest customer of scrap dealers selling aluminum beverage cans is SIC 3341, secondary aluminum manufacturers. Again, the scrap dealers are a good channel for reaching the manufacturers.

3. Quantities Desired for Purchase

a. Respondents expressed an interest in buying more than 41,728 tons of the described aluminum beverage cans, with 7 additional respondents desiring an unlimited quantity. This included 1,368 tons desired by respondents from the 9-county Bay area.

b. The entire supply of aluminum beverage cans available from the North County Project (Marin) can readily be sold, in that the given demand in the 9-county area alone is 111 percent of available supply. Scrap dealers are the primary market responding. Statewide demand is 3,387 percent of supply.

c. The average shipment of cans was 41 tons, representing 21 percent of the typical firm's needs for aluminum cans.

4. Advantages, Disadvantages, Changes Needed in Described Aluminum Cans

a. Profit is perceived as the number one advantage of the aluminum cans described, mentioned by 23 percent of all respondents, with another 18 percent noting "add supply", and 15 percent "clean up landfills".
b. Storage problems (23 percent) and contaminants (21 percent) are the major disadvantages.
c. Few changes were recommended to the physical make-up, chemical content, packaging, and delivery of cans described.

5. Current/Future Price Expectations

a. Price for the described aluminum cans was estimated to be $442 per ton today and $541 per ton in 2-3 years. Many respondents refused to estimate prices because of the unpredictability of market fluctuations.

6. Contractual Requirements Desired

a. Over 80 percent of those who have bought aluminum beverage cans in the past 12 months prefer to buy on an as needed basis rather than on a contract.
b. Primary guarantees requested in a contract to buy aluminum cans were guaranteed tonnage per month (33 percent mentioning), guaranteed price (26 percent), and guaranteed quality, with minimum contaminants (26 percent).
c. Most respondents who will buy in the future (90 percent) want some form of contract, with the most frequently requested time period being one year, and the contract being verbal.

d. Only 35 percent of the respondents would be at all likely to accept a floor price contract, while 36 percent would be likely to accept a "take or pay" contract.

e. Most respondents (69 percent) either requested no specific discounts or did not answer the question when asked what discounts they would expect.

7. Preferences Toward Type/Source of Supplier

a. Over 60 percent of the respondents would prefer dealing with a recovery plant which was completely private enterprise.

b. Most respondents (53 percent) want no government involvement in the recovery of aluminum beverage cans.

c. The most preferred source from which respondents would like to buy aluminum beverage cans are scrap dealers (mentioned by 67 percent).

d. The most frequently mentioned sources of availability and prices for aluminum beverage cans were the secondary aluminum mills, foundries, smelters, and ingot manufacturers (mentioned by 21 percent), dealers (21 percent), and primary aluminum producers (13 percent).

8. Summary of Calls to Can-Do Centers and Beverage Can Recyclers

a. It should be noted that, currently, there are a number of additional potential buyers for the aluminum beverage can stock in the State of California, including many brewers and beverage distributors, as well as volunteer recycling centers located in many cities throughout the state. These buyers, however, generally are intended to serve the general public and small collectors of aluminum beverage cans, and are generally not in a position to handle the comparatively large tonnages which might be recovered at a resource recovery facility.

Conclusion

The survey results indicate that sellers of recovered aluminum cans would realize more revenues by selling to secondary aluminum manufacturers, rather than to scrap dealers. In addition, the price for aluminum cans is expected to rise by $100 per ton in 2-3 years, thus improving the economics of aluminum can recovery.

C. Glass Cullet

A common view is that glass containers would be the most readily recyclable of all the packaging materials, but in fact purchased scrap glass has one of the lowest recycling rates of all the packaging materials. This is due in part to the difficulty in color sorting glass as well as meeting the required GCMI minimum contamination level. A cullet sample recently sent to Glass Containers Corporation (GCMI) contained 96 percent glass, 3.5 percent ceramics and stone, and .5 percent of other. The sample was rejected because of the contaminants.

Markets

In the Bay Area there are some users of cullet (including color sorted and mixed) who could use significant quantities. However, these users have decided preferences for in-house generated cullet, as it is of a known and uniform quality. Purchased cullet, unless tested, is of an unknown quality. Purchased cullet must meet Glass Container Manufacturers Institute's (GCMI) technical standards. Even if purchased cullet meets GCMI's standards it is not necessarily considered by the industry to be a substitute for its current raw material. The reason for this attitude is a highly perceived risk of off-batch losses because of contaminants.

In addition, it appears that even if the technical problems could be resolved there is a reluctance on the part of the glass industry to purchase cullet from a single source. Therefore, several recovery facilities would be needed to overcome the industry vulnerability to a sole supplier.

The Barasch Study[1] provided the following results with respect to the hand-sorted glass cullet market:

1. Respondents' Past Experience With Handsorted Glass

   Nine of the eleven respondents to this survey noted that in the past 12 months, they had regularly purchased handsorted flint color cullet. One respondent indicated that they had only experimented with this material, and one had only heard of the material.

2. Willingness to Buy Described Handsorted Cullet

   Five of the nine respondents who currently buy noted that they would definitely buy the material as described in the survey. Another three respondents indicated that they would consider buying, and one said he definitely would not buy.

3. Quantities Desired for Purchase

   a. Six respondents indicated an amount that they would be willing to buy, and another respondent indicated that he would purchase an unlimited amount. The total tonnage statewide that they would purchase was 127,006 tons.
   b. The entire supply of handsorted flint color cullet could be purchased within the 9-county area (137 percent of supply). Another 526 percent of this material could be purchased from outside the 9-county area. Therefore, it appears that with demand at a level of at least 663 percent of available supply, it would be very feasible to expect that the entire supply would in fact be purchased, and

a recovery facility for this product would be a viable enterprise.

4. Advantages, Disadvantages, Changes Needed in Described Handsorted Cullet

   a. The most important advantage perceived was that this material would reduce the fuel consumption in the manufacture of glass (noted by 3 of the 7 respondents in SIC 3221).
   b. The major disadvantages noted (by 2 respondents each) were the handling costs and contamination problems.
   c. No specific changes in the described product would be necessary in order for companies to buy.

5. Current/Future Price Expectations

   a. Price for the described handsorted glass cullet was estimated to be $31 per ton today and $40 per ton in 2 to 3 years. However, it must be remembered that this response is based on only nine answers. Two of the respondents noted that it was impossible to predict what the price might be.

6. Contractual Requirements Desired

   a. Eight of the nine respondents noted that their current needs are met on an as-needed basis rather than through a contract. However, if they were to have a normal contract, 4 of the respondents indicated a one year period to be the most desirable; 1 a 2-5 year period; 1 a 6-12 month period; and 1 said he would be unwilling to accept a contract.
   b. When asked if they would accept a floor price contract, 44 percent said they would be somewhat likely to do so, 11 percent somewhat unlikely, 11 percent extremely unlikely, and 33 percent said they did not know.

c. When asked how willing they would be to accept a "take or pay" contract, no respondents indicated they would be likely to do so, while 22% said they would be somewhat unlikely 33 percent said extremely unlikely, and 44 percent said they did not know.

d. When asked what types of discounts they would like to have in a contract, only one respondent indicated an interest, and that was in a quantity-type contract.

7. Attitudes Toward Government Involvement

Only two of the respondents specifically stated that they were in favor of a completely private enterprise operation. Two others said it did not matter to them, and others opted for a publicly owned and operated or other quasi-publicly operated facility. Respondents felt that government involvement should center around providing facilities, cooperatives for transportation, some financial aid to get the business going, and ordinances to direct the public in the collection of the glass.

Conclusion

The data indicate that there could be viable markets for several thousand tons per month of cullet in the primary glass manufacturing industry in California. Subjective information indicates that glass manufacturers are reluctant to purchase recovered cullet from a sole supplier. Resource recovery facilities would therefore find it necessary to deal with more than one glass manufacturer for the purchase of their cullet.

D. Fiber (Wastepaper)

In 1970, about 60 million paper products were consumed in the United States. Roughly 45 percent of this wastepaper can be source separated and classified into two main categories: corrugated and newsprint. If the paper is left in the waste stream, it can be recovered as a mixed paper waste or as a fiber pulp. On the other hand, should recovery facilities decide to do so, the fiber may be combusted and utilized as an energy source if the market is available. Source separation could be attractive, but the effects on the market place from such activities are as yet undetermined.

Markets

The secondary fiber share of the paper market in the United States has declined from 35 percent in 1944 to about 18 percent in 1973. In 1973, the United States wastepaper consumption stopped its downward trend and its market share increased from 18 percent to 20 percent during the years of 1973 to 1975. The American Paper Institute expects this trend to continue through 1980 at about a one percent increase per year.

In California there are four paper market areas, including export markets.

The first is paper manufacturing companies. These companies could be a viable market for source separated newsprint and corrugated paper products. Terms of the contract for purchase will have to be negotiated, as generally they will enter a "floor price" contract. Paper companies have specific preferences for ledger grades, or corrugated and newsprint.

Another market is dealers and brokers for various paper grades ranging from computer tab cards to mixed paper wastes. Because of the broad categories of paper handled, these firms are interested in the possiblity of purchasing recovered pulp from secondary sources. Indications are that they could utilize several hundred tons per day of mixed paper wastes.

Two companies use wastepaper to generate completely different end products. One company manufactures roofing paper and other shelter-related products, and has indicated that waste material is completely acceptable for the manufacture of roofing paper. It is still unknown in what quantities and at what price that firm would be willing to contract. Another company is currently purchasing and utilizing wastepaper in its manufacture of gypsum "dry-wall" sheets. Although this firm has expressed interest in trying to use refuse-derived mixed paper wastes, it is concerned that the plastic in the waste stream might appear on the surface of the sheets and degrade the product. No quantities or prices were determined, as product quality was an unknown factor.

The Barasch market survey for newsprint supplied the following findings:

1. Respondents' Past Experience With Old Newspaper

   a. Ninety-two percent of the survey's respondents purchased some quantity of old newspaper in the past 12 months.
   b. Eight SIC's noted past purchase or use of old newspaper: paperboard mills (SIC 2631), pulp goods (SIC 2646), paper products, converted (SIC 2649), wallboard and building paper (SIC 2661), wastepaper dealers (SIC 5093), exporters (SIC 26200/500), wastepaper dealers (SIC 5093W and SIC 5111).
   c. The 22 repondents who had made purchases in the past year were asked to describe their purchases. Most of them simply indicated that they bought newspapers either baled or loose; some noted that they bought from paper drives at schools, churches, etc.; others indicated that they bought over-issues.
   d. In the past 12 months, 5 manufacturers noted that they produced an average of 7,900 tons per month of recovered old newspaper in-house, for a total of 39,500 tons.
   e. In the past 12 months, 22 respondents noted that they bought a total of 644,190 tons, or an average of 37,894 tons per company.

f. The price per ton paid for old newspaper in the past 12 months ranged from a low monthly average of $28, both in the 9-county area and elsewhere, to a high monthly average of between $32 and $42, with the higher figure being the purchase price in the 9-county area.

g. The most prevalent sources from which companies bought were: scavengers/junkmen (68 percent); neighborhood recycling centers (45 percent); direct from landfills (55 percent).

h. On the average, companies traveled 23 miles to the original source of the newspaper they bought.

i. Fifty-five percent of the respondents indicated some problem with either the supplier or the old newspaper. Many of the complaints centered around increasing the weight by the insertion of magazines into the material (15 percent). Others complained of lack of steady supply, moisture, and other contamination.

2. Willingness to Buy Described Old Newspaper

a. Seventy-one percent of the respondents said that they would definitely buy the old newspaper as described in the study, and another 12 percent said that they would not consider buying.

b. The few respondents not interested in buying the described old newspaper simply said they had no use for it in their particular operation.

c. The single largest customer of scrap dealers selling old newspaper was paper mills, SIC 2621 (92 percent), followed by exporters, SIC 26200/500 (77 percent).

3. Quantities Desired for Purchase

a. Respondents expressed an interest in buying more than 713,824 tons (4 companies did not specify an amount). This included 41,624 tons in the 9-county area alone.

b. The entire available supply can easily be utilized in the 9-county area by 6 of the 8 SIC's responding. All 8 could utilize 1,056 percent of the available supply, with the primary market being scrap dealers not elsewhere classified. The statewide demand is 18,108 percent of supply.

c. The average quantity per shipment is 22 tons. This represents 49 percent of a typical company's needs for old newspaper.

4. Advantages, Disadvantages, Changes Needed in Described Old Newspaper

a. The guaranteed source was the most frequently mentioned advantage to the described old newspaper (27 percent). Others mentioned the value of saving virgin resources, increasing their sales volume, and liking the contract arrangement.

b. The most frequently mentioned advantages of buying the old newspaper centered around the concern over moisture, contamination, and price fluctuations.

c. Only 6 changes were recommended by the 22 respondents. Most significant of these were that two respondents (9 percent) wanted more of the foreign material removed, and one other was concerned about the overall quality of the described material.

5. Current/Future Price Expectations

a. The average price today statewide is estimated to be $34 per ton, and the price 2 to 3 years from now is expected to rise to $39. Eight of the respondents declined to give estimates on some of the prices, apparently due to market fluctuation.

6. Contractual Requirement Desired

a. Eighty-two percent of those currently purchasing do so only on an as-needed basis. Four others have both contracts and buy on an as-needed basis.

b. Guarantees or commitments that respondents felt would be needed before serious negotiations could take place centered around some protection from the widely fluctuating price (about 32 percent of the respondents). About 24 percent felt that some guarantee as to volume would be mandatory.

c. Of the 22 respondents, only 4 said that they would be unwilling to accept any kind of contract. The most commonly desired time period was the one year period (27 percent). This was followed by those interested in a 6-12 month contract (23 percent).

d. Thirty-seven percent of respondents said they would be either extremely or somewhat likely to accept a floor price contract. Only 23 percent indicated any interest in a "Take or pay" type contract.

e. Only 23 percent of the respondents expressed any interest in discounts being provided, and these centered around quantity and cash discounts.

7. Preferences Toward Type/Source of Supplier

a. Fifty-nine percent of the respondents would prefer dealing with a recovery plant completely owned and operated by private enterprise. The other respondents had no preference.

b. Only 36 percent of the respondents had any suggestions for ways in which government should be involved, with the remainder feeling the government should stay completely out of this area.

c. The majority of respondents preferred to deal directly with the public (73 percent). This was followed by 50 percent of the respondents indicating they would probably buy from recycling centers, scavengers/junkmen, and/or dealer-processors. The only group from which less than half would plan to buy were brokers and direct from landfills.

d. The most frequently mentioned key sources of information on availability and prices for old newspaper were industry publications, such as the Yellowsheet and Boardmarkets (18 percent). Others indicated they would make direct contact with dealers, brokers, and others involved in the business.

Development and Projections

It was also found that prices generally swing up in the months of October through December and decline for the remaining part of the year. Some major paper companies are considering developing large inventories of scrap paper to even out these fluctuations.

Conclusion

Of all the markets studied, the fiber market appears to be the most volatile. This market is not only seasonal, with higher prices during winter months, but also seems subject to five-year cycles with unpredictable swings within those cycles. Caution should be exercised when dealing with this market.

III. IMPACTS ON THE MATERIALS MARKET BY MARKETING PROGRAMS SPONSORED BY THE STATE OF CALIFORNIA

The Solid Waste Management Board has considered several proposals to stabilize market volumes and prices. These proposals have been an outgrowth of many requests from the public and from private firms for the State to assist in marketing of recovered materials.

The proposals which have been considered by the Board are as follows:

Test Market Programs

Develop new markets through test marketing techniques. One example would be to produce and test market mixed cullet beverage bottles in the Sacramento area. If successful, the program could be used as a data base to help convince bottlers of no adverse affect in their product sales due to the color of the bottle. This program would have to be implemented by an outside marketing consulting firm. The total contract price to produce the bottles and all costs associated with this test market program is estimated at $350,000-$400,000.

State Supported Tax Incentive Programs

The State could give tax support for the purchase of either secondary materials in the manufacture of new goods or equipment needed to manufacture new goods from secondary materials. This program could stimulate industrial purchase of secondary materials or the making of new goods using recycled materials.

Legislative Programs

The State could require that a specified percentage of recycled materials be used in the manufacture of certain new products. This Legislature program would be developed by State Solid Waste Management Board staff, with the intent of providing consistent volumes of recovered materials to buyers. One target for such legislation could be the packaging industry.

State Procurement Policy Program

The objective would be to stimulate the purchase of recycled materials, such as recycled office paper, where possible, or the use of secondary materials in the construction of new State buildings.

Redeemable Coupon Programs

Products made from recyclable materials could contain coupons redeemable for cash through the Solid Waste Management Board or through local recycling centers. This program would generate a measurable demand for these kinds of products from the consumer, but would require a revolving fund in excess of one million dollars to implement.

Centralized State Clearinghouse Programs

The Board would be a central point for the listing of products for sale and for the listing of buyers of such products. The intent of this program would be to respond to rapid changes in market conditions by listing any changes of market conditions and prices of buyers. A clearinghouse may be implemented in California by Board staff or by private organizations which have the resources to implement such programs.

Research and Development Programs

The State could sponsor an experimental factory capable of producing various kinds of secondary materials and recovered energy. It would be designed to generate large amounts of materials and energy so that industrial experiments with using secondary products could yield realistic marketing data. This would be a multi-million dollar experimental factory, requiring large capital investment and more than 100 individuals to operate and maintain.

State Sponsored Price Support Program

The State could guarantee to purchase all secondary material at a "fixed" price. This program would be similar to federal agricultural price support programs which have a standing offer to purchase all of a particular kind of product at or below average fixed price. This program could cost billions of dollars for purchase of materials. This type of program would also require warehousing capabilities, transport, marketing, and extensive staff support.

IV. IMPLEMENTATION OF PROGRAMS FOR STIMULATION OF MARKETS

The State Solid Waste Management Board has not yet implemented any comprehensive marketing programs. With the advent of grants from the Board to recycling centers and resource recovery facilities pursuant to the provisions of SB 650 however, the Board has a genuine need to protect its investments by promoting the effective marketing of recovered materials. As a result, Board staff are developing a comprehensive marketing program, based upon research consideration of public input. The major components of this program are to contract for computerized clearinghouse services and a request for funding to support a comprehensive workplan. These methods of Board marketing involvement are described in the following sections.

A. A private firm, World Association for Solid Waste Transfer and Exchange (WASTE), San Francisco, has established a computerized clearinghouse system for listing marketing information to help organizations find buyers who can recycle their wastes. The clearinghouse has collected and disseminated information on volume, quantity, availability, and location for secondary materials and has stored information in Control Data Corp's global Cybernet Computer network. The information is accessed via interactive terminals located in San Francisco. The Solid Waste Management Board has contracted with WASTE to provide recyclers, industry, brokers and dealers with a marketing environment in which sales transactions may take place independent of the Board.

B. The Board has applied for funding for fiscal year 1979-80 from the California Energy Commission to support a marketing program implementing many of the suggestions discussed in Section III (preceeding). The workplan and budget for this program are attached as Appendix F. Implementation of this proposal will further the recommendations of this report, and is expected to achieve significant increases in the volume of recycled materials delivered to and utilized by the marketplace.

REFERENCES - CHAPTER III

1. Kenneth L. Barasch and Associates, Executive Summary - Site Specific Market Study - San Francisco Bay Area. Prepared for the State Solid Waste Management Board, August 1978.

2. California State Solid Waste Management Board in-house memorandum from Hugh A. Walker to George Hersh dated May 12, 1978.

3. Elrick and Lavidge, Inc., Report Digests of Four Marketplace Studies Concerning: Aluminum Beverage Cans, Combustible Waste Fuel, Hydrogen, Piped-In Steam. Prepared for the State Solid Waste Management Board, April 1978.

CHAPTER FOUR

ENERGY CONSERVATION OPPORTUNITIES IN SOLID WASTE COLLECTION AND TRANSFER

I. Introduction

Collection techniques for municipal solid waste are often selected out of convenience to the owner/operator without adequate regard to possible energy waste. Within the area of urban refuse disposal, the commitment to the maximization of resource recovery with a minimum amount of energy expenditure is desirable, if not demanded by the energy-deficient future. A reduction in energy use within the collection and transfer processes without involving undue modification of existing operating procedures would be advantageous to both operator and consumer in that: 1) the profit margin for the operation may be increased because of less energy use and thus less energy cost, and 2) the cost to the consumer may be lowered as a result of reduced collection fees.

The purpose of this section is to provide comparative energy consumption values for various solid waste collection and recycling operations. Factors influencing energy consumption in the collection and transfer of both garbage and recycled materials will be identified and qualitatively characterized. Wherever possible, the energy values of each factor will be quantitatively assessed and the relative impact on the collection process discussed.

While assessments contained herein concern themselves primarily with the goal of decreased energy consumption, it should be understood that productivity will play a key role in determining feasibility of a particular collection operation. Thus, while a particular method might be the most energy conservative, it may also be economically prohibitive.

II. Methodology

The procedure used in assessing energy consumption was to first identify those factors of a specific collection system which are energy intensive (i.e. that particular activity in the collection or recycling process which consumes energy as electricity, gasoline, etc.) After each energy consumption component was identified, the weight of influence associated with each component which contributes to the overall energy use was assessed. An example of this is examining how and to what degree the number of miles on a particular collection route influences the number of gallons a collection vehicle will use. (Energy expenditures by labor were not considered because of their insignificance compared to energy consumed in fueling equipment.)

III. Factors Influencing Collection

There are two general categories of factors which influence energy use in collection: 1) intrinsic characteristics of the vehicle; and 2) characteristics of the collection route. Each factor has an influence on the amount of energy that will be used, in this case as either gasoline or diesel fuel.

A. Vehicle Characteristics

Vehicle size perhaps plays the greatest role in determining the energy cost intrinsic to any particular curbside collection vehicles, whether front, rear, or side loading.

Size efficiency can be characterized by the ratio of the carrying capacity of payload to the gross vehicle weight (GVW). Table 36 illustrates miles per gallon (MPG), payload to gross vehicle weight (Payload:GVW), and Btu per ton-mile for various collection vehicles under various driving conditions.

TABLE 36

FUEL CONSUMPTION BY VARIOUS COLLECTION AND TRANSFER VEHICLES

Vehicle & Travel	GVW (tons)	Payload:GVW	MPG	Btu/ton-mile
1) Gasoline pickup/van (trailer optional)	6	0.4		
Intermittent collec.			5.1	10,200
City			6.6	7,900
Suburban			7.4	7,000
Highway			7.6	6,900
2) 2-axle, 6 tire Diesel Truck	8	0.6		
City			4.0	7,200
Highway			5.0	5,800
3) 25 cubic yard packer Diesel Truck	25	0.4		
Collection			1.8	7,700
Highway			4.5	3,100
4) Diesel Roll-off	30	0.6		
City			4.4	1,700
Suburban			5.9	1,300
Highway			5.9	1,300

Sources:
Energy Factor Handbook
TCAPE
SWMB studies

The greatest fuel consumption in miles per gallon is in the 25 cubic yard side-loading packer. This particular vehicle has a low payload to GVW ratio compared to other comparable forms of commercial waste transportation. Allen Berger of Browning-Ferris Industries is quoted in Waste Age as saying, "We are the only industry I know of which hauls around more in the body than actual payload."[1] The fuel efficiency is low because of the heavy body, which is due to the weight of the hydraulic system. However, it can be seen that it is more efficient in Btu per ton-mile than the smaller modified van or the smaller 6-tire truck in both collection and highway travel. It is apparent that the packer refuse truck is the vehicle of preference in collection. There are smaller sized collection vehicles available in the 10 ton GVW, 12 cubic yard capacity range. While the payload to GVW ratio is low (approximately 0.3 to 0.4) they compensate with fuel efficiency and increased miles per gallon. Typically, these collection vehicles operate close to a local landfill or transfer station, or in conjunction with a larger vehicle which is used to transfer the waste from several 12 cubic yard bodies to a more distant landfill.

The collection vehicle of the future envisions a payload to GVW ratio of 0.5 with a maximum GVW of 60,000 pounds, the anticipated DOT 1985 requirement. A lighter frame construction using aluminum in the structure and front-end forks, a larger box and reduced chassis (a 30 cubic yard machine, 16,000 pound chassis with 14,000 pound box), increased hydraulic pressure, and 1,000 pounds of refuse/cubic yard should increase fuel efficiency by decreasing the amount of highway trip miles to and from yard and landfill.[2] Assuming two MPG, this vehicle will use approximately 4,600 Btu/ton-mile in collection.

At present, a large proportion of collection vehicles has an automatic power transmission with a single speed axle which allows for operation in congested traffic or in collection where constant shifting is necessary. The factor which will most influence the type of transmission and gearing in collection vehicles is the type of terrain over which the vehicle will travel. A more hilly terrain will usually demand a lower gear ratio.[3]

Other minor factors of the vehicle which influence fuel consumption are: 1) frontal area as a drag coefficient, 2) bias-ply tires versus radials (the most efficient combination for refuse trucks appears to be radials in the front and bias-ply in the rear), and 3) air-conditioning, oil coolers, and any additional equipment which reduces the driveline efficiency. In particular, the hydraulic system used in compaction will affect the number of miles per gallon on collection.

B. Route Characteristics

There are several factors of the route influencing energy consumption in operation of a collection system. These include payload of the vehicles, terrain of the collection route, time on the route, and total number of miles traveled on the route as well as the number of miles to and from the landfill. A sensitivity analysis done on variables affecting fuel consumption of a residential solid waste collector in California has shown that the total number of miles traveled in collection has the greatest impact upon gallons of fuel consumed.[4] The degree of influence of each of the factors will be discussed.

1. Collection Route

The greatest fuel consumption per mile will occur on the collection route. This is due to the constant idling, acceleration, and deceleration of the vehicle. A 25 cubic yard rear-loading packer with a 390 cubic inch displacement engine will consume 0.80 gallon/hour while idling. The amount of fuel consumed with more than 10 stops per mile, at a speed of 25 miles per hour in light traffic density, is greater than five times the fuel consumed if no stops are made.[5] (See Table 37.) This would infer that stops greatly contribute to fuel consumption. It is typical for 300 to 500 stops to be made per day by a curbside once-a-week collection truck.[6]

TABLE 37

RELATIVE FUEL CONSUMPTION OF 40,000 TO 50,000 LBS GVW ATTEMPTING 25 MPH WITH FREQUENCY OF STOPS

Traffic Density	Frequency of Stops Per Mile (per Km)										
	0 (0)	1 (0.6)	2 (1.2)	3 (1.9)	4 (2.5)	5 (3.1)	6 (3.7)	7 (4.3)	8 (5.0)	9 (5.6)	10 (6.2)
Light	1.00	1.39	1.78	2.18	2.57	2.96	3.35	3.75	4.14	4.53	4.93
Moderate	1.00	1.39	1.78	2.18	2.57	2.96	3.35	3.75	4.14	4.53	4.93
Heavy	1.00	N.A.	N.A.	N.A.	2.60	2.99	3.38	3.78	4.18	4.58	4.98
Congested	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	3.48	3.86	3.86	4.64	5.05

Source: Energy Factor Handbook

Decreasing the amount of fuel consumed during collection can be accomplished by reducing the idle time between stops. An analysis of 11 residential solid waste collection systems, referenced in Solid Waste Collection Practice, has shown that the present collection time, compacting time, and waiting time on route is not significantly different for either a one, two, or three-staff collection crew. However, when standardized to the number of tons of garbage collected per hour the three-staff crews cuts idle time to approximately half that of the one or two-staffed collection systems.[7]

Several mechanized one-staff systems are in effect across the country. These reduce loading time by not having the driver descend from the cab. These systems sometimes have a mechanical loading "claw" which grabs the residential waste container, lifts it to the hopper and automatically dumps the garbage in. Scottsdale, Arizona has used this system with good results.[8]

Another factor, collection density, can be increased by practicing two-sided versus one-sided residential collection. (Collection miles are reduced if both sides of the street are collected at the same time.) Another method of reducing fuel consumption is to design efficient heuristic micro-routing, reducing collection miles traveled; i.e., less miles traveled for the area needed to be serviced.[9]

2. Highway Miles

There are two ways of characterizing the number of highway miles: those miles from the route to the landfill, which are termed "heavy" miles in that the collection vehicle is usually full; and those miles from the yard to the route, from the landfill back to the collection route, and from landfill back to yard. These miles can be described as "light" miles in that the vehicle is usually empty.

Decreasing the number of highway miles traveled will decrease fuel consumption. Because the collection vehicle consumes more fuel when full then when empty, the yard should be located in the most centralized location practical to the distribution of routes, and the distance to landfill should be as short as possible; collection should start at the point on the route furthest from the landfill.

TABLE 38

RELATIVE DIESEL FUEL CONSUMPTION 40,000 TO 50,000 LBS. GVW GRADE VS. FLAT LAND

Constant Speed MPH	(Km/Hr)	Ascending Grade									
		1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
10	(16)	1.14	1.28	1.42	1.55	1.82	2.08	N.A.	N.A.	N.A.	N.A.
20	(32)	1.17	1.17	1.58	1.82	N.A.	N.A.	-	-	-	-
30	(48)	1.62	2.23	N.A.	N.A.	N.A.	-	-	-	-	-
40	(64)	1.64	2.27	N.A.	-	-	-	-	-	-	-
50	(80)	N.A.	N.A.	-	-	-	-	-	-	-	-

Constant Speed MPH	(Km/Hr)	Descending Grade									
		1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
10	(16)	0.70	0.41	0.37	0.34	0.34	0.34	0.34	0.34	0.34	0.34
20	(32)	0.67	0.33	0.30	0.26	0.26	0.26	0.26	0.26	0.26	0.26
30	(48)	0.70	0.40	0.32	0.24	0.24	0.24	0.24	0.24	0.24	0.24
40	(64)	0.79	0.56	0.40	0.25	0.25	0.25	0.25	0.25	0.25	0.25
50	(80)	0.84	0.67	0.49	0.21	0.21	0.21	0.21	0.21	0.21	0.21

Source: Energy Factor Handbook

3. Other Factors

Other factors will have an effect upon total fuel consumption; most notable is the type of terrain on route. A 25 cubic yard gasoline packer maintaining a constant speed of 20 miles per hour up a 6 percent grade will consume approximately four times the amount of fuel as on flat land; the truck descending will consume 0.3 times the amount.[10] (See Table 38.) Optimum fuel economy would be realized by ascending the hill with the truck empty and collecting going down the hill, and by minimizing climbing hills by collecting across the grade rather than up or down.

IV. Garbage Collection and Recycling

The composition of residential solid waste changes from day to day, truck to truck, and season to season, as well as locality to locality. General trends are observable but the number of factors in waste composition influenced by local and world conditions are altogether too numerous to characterize. Therefore the figures presented herein should be used as averages subject to adjustment by local sampling.

Factors influencing garbage curbside collection will similarly influence curbside recycling operations, whether accomplished as separate collection systems or as systems integrating collection of garbage and recyclables. The number of recycling setouts will typically be a fraction of the number of garbage setouts and the quantity in volume and weight will be less. An ideal curbside recycling operation with collection of newsprint, mixed glass, aluminum cans, and other metals would collect approximately 8 pounds of recyclable materials per week from single-family residences in metropolitan areas.

The potential fraction of recyclables that can be considered as collectable by a curbside collection system is roughly 20 percent by weight of all household refuse.[11]

The volume of the recycled materials will also be a factor in determining the type of collection vehicle for either separate or integrated curbside collection. From various Solid Waste Management Board studies of different recycling operations, the relative proportions of recyclables collected by weight and volume are:

TABLE 39
DENSITY, WEIGHT, AND VOLUME COMPOSITION OF RESIDENTIAL RECYCLABLES

Material	Density[12]	Percent by Weight	Percent by Volume
Newsprint (stacked)	2.5 cu.yd./ton	54.8	62.8
Glass (partially crushed)	1.5 cu.yd./ton	34.8	23.9
Aluminum (partially crushed)	4.9 cu.yd./ton	1.3	2.9
Ferrous (partially crushed)	2.5 cu.yd./ton	9.1	10.4

It can be seen that the greatest portion of the capacity of a recycling collection vehicle should be devoted to newsprint, with the remainder of the available space split between unbroken mixed glass and bi-metal cans. The volume of aluminum collected (usually as cans) will be small compared with the other recyclables.

A. Factors Influencing Integrated Curbside Recycling

An integrated curbside recycling program is defined as the collection of recyclables using the same vehicles used for garbage collection. Typically, recycling bins are attached to the sides of the garbage collection vehicle or, for newsprint, a rack is mounted under the hopper. Recyclable materials are usually placed on the curb separate from garbage. In an integrated program the number of route miles will be the same with recycling as without recycling. The number of highway miles will differ in that:

1. The truck will have to travel to the recycling yard either before or after landfilling the garbage, unless the recycling yard is located at the landfill.

2. "Heavy" miles versus "light" highway miles will have to be determined by the relative distances from the route. For example: it would be more energy efficient to go to the landfill first and unload the heavier garbage (80 percent by weight) than to go to the recycling yard first if the route is closer to the landfill than it is to the recycling yard.

There will be a slight increase in idle time per pickup due to an increased amount of time for placing the recycled materials in their appropriate bins.

One of the greatest problems with an integrated collection system is that of providing adequate space on the truck for collection of recyclable materials. The recycling bins may fill to capacity before the truck fills with garbage. What results, then, is one of three things: first, the crew stops collecting recyclables, collects garbage until full, then goes to the landfill and yard. Second, the crew goes directly to landfill and yard, before the truck is filled to capacity with garbage. (While this decreases "heavy" route miles, it does provide the system with a degree of non-productivity because the truck does not collect to its potential.) Third, the crew puts recyclables in with the garbage until the garbage is full. The latter will not increase route miles but does deter from the recycling program. Thus, the recycling bins should be designed in proportion to the amounts of recyclables and garbage in the collection area as ascertained by local waste composition analyses.

B. Factors Influencing Separate Collection Recycling

Assuming the recycling vehicle travels the same route as the garbage collection vehicle, the number of route miles will be the same for each vehicle. The number of highway miles, both heavy and light, will be influenced by the distance from the route to the recycling yard and not by the distance from the route to the landfill.

The type of vehicle will affect the amount of energy spent on collection. Usually, recycling vehicles are smaller than garbage collection vehicles because of the lesser volume of recyclables. A smaller capacity vehicle, while achieving better fuel economy, will have an increase in the number of highway miles, both heavy and light; on the other hand, a greater carrying capacity vehicle, while having lower fuel economy, will travel fewer highway miles.

V. Energy Consumed In Collection of Refuse

A study conducted by the State Solid Waste Management Board on a Northern California community residential collection service provides information on energy of collection and transport of residential waste. The results are included in the Material Handling Section, Table 3. Summarized, 0.17×10^6 Btu/ton are required for collection and 0.06×10^6 Btu/ton are required for transport of residential waste, assuming approximately 20 miles on both route and highway for a 25 cu. yd. packer truck. The combined amount, 0.23×10^6 Btu/ton, yields a collection and transport figure of 5,500 Btu/ton-mile. This is a low figure compared with the other modes of refuse collection described in Table 36.

VI. Conclusions

Aside from using the most efficient collection vehicle available, there does not appear to be any significant energy conservation improvements that can be made to the refuse collection equipment. It is desirable in terms of energy conservation to reduce the number of collection and highway miles by establishing transfer and landfill sites at minimal distance from collection routes. Likewise, time spent on collection should be minimized.

In considering the overall energy picture, the energy consumed in collecting and transporting refuse and recyclable materials is small compared with the potential energy reduction which may be gained from the use of secondary materials in the manufacturing process.

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CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS
SECTION 1 - CONCLUSIONS

Chapter One - Source Separation Energy Consumption/Conservation Analysis

1. Material Handling

The total average energy that is necessary to landfill municipal solid waste is estimated to be 0.26 x 10^6 Btu/ton MSW. The energy components are identified as follows:

Administration and Maintenance	0.01 x 10^6	Btu/ton MSW
Collection	0.17	"
Transport to Landfill	0.06	"
Landfill processing	0.02	"

The energy expenditure for the collection of recyclable materials for various labor intensive collection systems is identified below:

Drop-off Center	2.23 x 10^6	Btu/ton recyclables
Drop-off mobile Center	0.92	"
Separate Curbside collection	0.23	"
Integrated Curbside collection	0.23	"

In processing recyclable materials, the energy expended was determined to be 0.08 Btu/ton recyclables.

A Capital-Intensive Resource Recovery system was characterized. It was found that this facility produced a net energy gain of 4.70 x 10^6 Btu/ton of MSW which includes all internal energy costs. The net electricity generation conversion factor based on the Ames, Iowa, facility is calculated at 21,000 Btu/kwh using an RDF heating value of 5,600 Btu/lb. California heating value for RDF is found to be 4800 Btu/lb. and with a 40% moisture content.

2. Glass Containers

The weighted average energy used in the production of one ton of glass container for California is 13.49 x 10^6 Btu/ton of glass container. This is lower than the estimated national average of 16.23 x 10^6 Btu/ton container. Assuming a 50% cullet level, (which is above the current 20% used in the State), and a 15% furnace energy savings, the energy expenditure for the production of glass containers is 12.33 x 10^6 Btu/ton container or an energy saving of 8.6%.

3. Aluminum Containers

Aluminum can manufacture is very energy intensive compared with the manufacture of other products considered in this report. Using virgin materials, the total energy used to produce 1 ton of aluminum cans is 313.56 x 10^6 Btu/ton. The same production using approximately 100% recycled cans comes to 106.69 x 10^6 Btu/ton container, an energy savings of 66.0%. This savings is not entirely realized in California but its impact can be felt in this State.

4. Newsprint

The initial manufacture of newsprint using virgin material takes place outside the State. Newsprint using post consumer generated material is produced for the most part within the State. Starting at the point of transport of virgin materials to the pulp mill and ending at the printing plant in California the energy involved in the combined processes is calculated at 21.29 x 10^6 Btu/ton newsprint product. Using 100% recycled newspaper, the energy consumed is 16.74 x 10^6 Btu/ton newsprint, or an energy savings of 21.4%.

5. Ferrous Containers

Because recycled steel containers are not used in the manufacture of new steel containers, energy comparison or energy saving figures

SUMMARY TABLE 40a

ENERGY CONSUMPTION IN THE ALUMINUM CAN INDUSTRY (1)

STEP IN PROCESS	100% VIRGIN (x10^6 Btu/ton of ALUMINUM)	100% RECYCLED (x10^6 Btu/ton of ALUMINUM)	
		(Virgin)	(Recycled)
Mining & Transport	46.68	6.54	
Residential Collection (2)			0.31
Shredding(3)			1.80
Transport to Manufacture			1.03
Ingot Manufacture	205.25	28.73	5.85
Casting to Can Manufacture	61.61	61.61	
Landfill Residue	0.02 (4)	0.02	
TOTAL	313.56	106.69	

Energy Savings of 66.0 percent (5)

Notes:

(1) For production of 1 ton of aluminum can product.
(2) Assumed Separate Curbside Collection and processing.
(3) Assumes some primary shredding at manufacturer.
(4) Landfill energy @ 7% times 0.23 Btu/ton.
(5) Energy savings is California specific to aluminum beverage industry; however, energy savings is not entirely realized in California.

SUMMARY TABLE 40b

ENERGY CONSUMPTION IN THE GLASS CONTAINER INDUSTRY (1)

STEP IN PROCESS	100% VIRGIN (x10^6 Btu/ton GLASS)	50% VIRGIN/50% RECYCLED (x10^6 Btu/ton of GLASS)	
		(Virgin)	(Recycled)
Mining Raw Materials or Collection (2)	1.82	0.91	0.15
Transport to Manufacture	0.25	0.13	0.16(3)
Furnace	5.88	2.94	2.50
Other(4)	5.54	5.54	
TOTAL	13.49	12.33	

Energy Savings of 8.6 percent

Notes:

(1) For the production of 1 ton of glass bottle product.
(2) Separate Curbside Collection and processing assumed.
(3) Transport from recycling center to manufacturer.
(4) Includes casting, forming, annealing, etc.

SUMMARY TABLE 40c

ENERGY CONSUMPTION IN THE NEWSPRINT INDUSTRY (1)

STEP IN PROCESS	100% VIRGIN ($x10^6$ Btu/ton of NEWSPRINT)	100% RECYCLED ($x10^6$ Btu/ton of NEWSPRINT)
Harvest or Residential Collection (2)	N/A	0.36
Transport to Manufacture	0.59 (3)	0.39
Manufacture	19.94	15.54
Transport to Newspapers	0.76	0.44
Landfill Residue	- (4)	0.01
TOTAL	21.29	16.74

Energy Savings of 21.4 percent

Notes:

(1) Based upon 1 ton of newsprint product.
(2) Assumed Separate Curbside Collection and processing.
(3) 50% moisture content of green wood (pulpwood and sawmill residue to pulp plant).
(4) Negligible waste.

could not be developed. With the advent and increased use of tin-free-steel (TFS) in container manufacture and with future market expansion, this information may become more readily available.

6. Summary

Summary Tables 40a, 40b, and 40c described the energy savings which are attributed to recycling aluminum containers, glass containers, and newspapers. Ferrous scrap has been excluded.

Chapter Two - Energy Conservation Cost Analysis

The cost of transporting recovered materials to market can be a major expense for recycling centers. Transportation costs vary according to the distance to market, the tons per month (TPM) shipped, and the type of transportation used. Private vehicle ownership appears to be the most cost effective method of material transport for greater distances to market and higher TPM hauled. For lower TPM and shorter distances to market, vehicle rental appears to be the least expensive method of shipping goods to market. Shipping by PUC MRT-2 rates does not appear to be cost effective except under certain limited conditions where volumes (or TPM) are low.

The various type of recycling centers become cost effective at certain levels of throughput. For lower throughput tonnages (20 - 50 TPM) the community drop-off center is the most cost effective system. As tonnage increases over 100 TPM, the following centers are ranked as to their cost effectiveness:

1. Integrated curbside collection with aluminum buy-back.
2. Multi-material Buy-back
3. Integrated curbside without aluminum buy-back.
4. Separate curbside collection with aluminum buy-back.
5. Separate curbside collection without aluminum buy-back.

The addition of an aluminum buy-back program to any resource recovery system contributes significantly to its economic viability.

Based upon the two proposed high-technology systems for California, it appears that there will be a net loss per ton of between $10 to $20. Although a considerable amount of material will be recycled and energy produced from the burning of RDF, operational expenses will have to be offset by either a tipping fee or government subsidy. This system may be quite economically acceptable in areas with existing comparable solid waste disposal charges.

Chapter Three - Identification of Secondary Materials Market and Variables Affecting That Capacity

Refuse derived ferrous scrap has a market in the Bay Area consisting of secondary scrap dealers and steel can processors. Prices tendered for ferrous scrap range from a current $44 to a projected price of $55/ton in the near future.

More revenue can be realized selling recovered aluminum cans to secondary manufacturers rather than to scrap dealers. The price of aluminum is expected to rise by $100/ton in the next 2-3 years in the Bay Area.

The glass manufacturing industry provides for a viable market in cullet of several thousand tons per month. Subjective information indicates that glass manufacturers are reluctant to purchase recovered cullet from a sole supplier. Resource recovery facilities would therefore find it necessary to deal with more than one glass manufacturer for the purchase of their cullet.

The most volatile market of the materials studied appears to be the fiber market. Seasonability and five-year cycles impact on market stability. Caution is necessary in dealing with this market.

Chapter Four - Energy Conservation Opportunities in Solid Waste Collection and Transfer

Aside from using the most efficient collection vehicle available, there do not appear to be any significant energy conservation improvements that can be made to the refuse collection equipment. It is desirable in terms of energy conservation to reduce the number of collection and highway miles by establishing transfer and landfill sites at minimal distances from collection routes. Likewise, time spent on collection should be minimized.

In considering the overall energy picture, the energy consumed in collecting and transporting refuse and recyclable materials is small compared with the potential energy reduction which may be gained from the use of secondary materials in the manufacturing.

SECTION 2 - RECOMMENDATIONS

This report has examined the energy requirements for products using virgin materials versus those for using recycled materials, specifically with respect to the manufacture of aluminum cans, glass bottles, newsprint, and steel. It has been established that the use of recycled aluminum, glass and paper products results in significant savings of energy in product manufacture. Based on this finding the State of California and all State Agencies should actively support, to the extent possible, recycling and resource recovery of those materials. It is therefore recommended that:

State Solid Waste Management Board

1. The Board should develop background information to determine the effectiveness of programs requiring the use of recycled materials in the manufacture of specified products.

2. The Board should develop background information to determine the effectiveness of programs providing tax incentives for the use of recycled materials in product manufacture.

3. The Board should develop background information to determine the effectiveness of programs providing tax disincentives for the use of virgin materials.

4. The Board should develop background information to determine the effectiveness of programs to stimulate public agency procurement of products wholly or partially derived from recycled materials.

5. The Board should develop background information on public agency participation in the recycling of aluminum, glass, paper products, and other recyclables.

6. The Board should develop background information to determine the effectiveness of requiring State contractors to use recycled materials whenever possible.

7. The Board should implement a State clearinghouse function to serve as an information exchange and a listing of markets, recycling centers, resource recovery facilities, and agency or industry contacts.

8. The Board should develop uniform cost-accounting and market reporting mechanisms for monitoring of the recycling center operations of SB 650 grant recipients.

9. The Board should collect secondary material marketing information to assist in the review of SB 650 grant requests, and to aid in providing technical assistance to recycling centers.

Other State Agencies and Local Governments

1. The Public Utilities Commission Code should be amended to provide for an exemption allowing private highway carriers, as well as carriers regulated by the PUC, to be free to participate in recyclable material traffic.

2. The PUC should, in the interim, authorize a commodity exemption for commodity and private debris haulers so that negotiated tariff rates can be responsive to market conditions.

3. The local governments, in providing refuse collection services, either franchised or public, should develop programs to increase energy conservation through the reduction of vehicle miles traveled and collection time. It is recommended that the COLMIS program of collection management information for solid waste be considered as a tool to achieve these goals.

4. Legislation should be developed to exempt buy-back centers from the weighmaster's bond requirements.

Recycling Industry and Other

1. The recycling industry should increase its efforts in research and development to expand the uses and markets for secondary materials. In areas where such efforts are particularly lagging, the State Solid Waste Management Board should take an active role in research and development.

2. The recycling industry should initiate serious investigation into the feasibility of a statewide non-profit transportation cooperative, operating solely for the purpose of providing less expensive transportation of recycled materials generated by recycling centers.

3. Backhauls should be encouraged through a statewide information system which would distribute information regarding the location of materials ready for transport.

4. Recycling centers should implement or expand buy-back programs for aluminum cans to increase profit.

5. When possible, recycling and resource recovery facilities should shred aluminum cans to achieve the greatest return on investment.

APPENDIX A

ALUMINUM INDUSTRY QUESTIONNAIRE

FOR PRIMARY PRODUCERS:

1. How much do you receive of the following:

	BAUXITE (IN TONS/YR)	MODE OF TRANSPORT	ALUMINA (IN TONS/YR)	MODE OF TRANSPORT
A. Caribbean				
B. S. America				
C. Australia				
D. Europe				
E. Other				

2. Do you produce alumina at the same location as aluminum?

3. How much aluminum can stock do you produce for California consumption?

4. Information we have gathered on primary production indicates the following energy consumptions:

USING VIRGIN MATERIALS ONLY

A. Alumina Production via the Bayer Process	37.25×10^6 Btu/ton of aluminum
B. Aluminum Production via the Hall-Heroult Process	168.00×10^6 Btu/ton of aluminum

If your processes or energy values differ from these, please indicate.

FOR RECYCLED/SCRAP ALUMINUM CAN USERS:

1. How much aluminum can scrap does your company receive from California?

   A. By Truck __________________ tons/year

   B. By Rail ___________________ tons/year

2. Where does your company shred and re-melt scrap aluminum cans that are collected in California?

3. How much energy is used in processing can scrap? (i.e., Btu/ton of scrap aluminum; kwh/ton of scrap; cubic feet national gas/ton of scrap; gallons of fuel oil/ton of scrap)

	Energy Expended in Each Step (Please Indicate Units)
A. Shredding/Baling	
B. Scrap Transportation	
C. Delacquering and Remelting	
D. Other (Describe)	
E. Total	

4. What percentage of scrap do you usually use in can stock production? Of this percentage what portion is can scrap?

5. Is it possible for you to use 100 percent recycled aluminum to make aluminum cans?

6. How much aluminum can stock produced from recycled material is sent to California?

7. Information we have gathered on recycled cans indicates the following energy consumptions:

USING CAN SCRAP

A. Shredding	1.94
B. Transportation	.46
C. Delacquering and Melting	6.32
TOTAL	8.72×10^6 Btu/ton of Scrap Aluminum

Does your experience substantiate these figures?

APPENDIX B

SURVEY OF NEW ALUMINUM PRODUCTION TECHNOLOGIES

I. ALTERNATIVES

The following processes are based upon using domestic sources such as alunite, kaolin, and anorthosite clays in place of imported bauxite, reducing U.S. dependence on foreign sources of raw material, and in turn reducing the amount of energy consumed during transportation. Although these processes themselves do not necessarily reduce energy consumption, they vary in the amount of pollution that they produce, which is often less in amount than that produced by the Bayer process.

A. Nitric Acid Leaching Process

The nitric acid ion exchange process involves the following steps:

1. Calcining kaolin clay to make the contained alumina selectively available for extraction with nitric acid;
2. Leaching the calcined clay with hot nitric acid at atmospheric pressure to produce a solution of aluminum nitrate and a suspension of the clay insolubles;
3. Separating the clay-insolubles from the aluminum nitrate liquor in thickeners;
4. Removing the iron and other impurities from the clarified aluminum nitrate liquor by use of liquor ion-exchange medium;
5. Removing the remaining impurities from the iron-free aluminum nitrate liquor by means of vacuum crystallization of aluminum nitrate monohydrate;
6. Recovering the alumina by hydrolysis of the aluminum nitrate under controlled conditions so that the nitrate values are recovered largely as nitric acid rather than as nitrogen oxides;

7. Recovering the nitric acid and nitrogen oxide values in the form of nitric acid for recycle; and
8. Calcining the product alumina.

Discharge from this process, although smaller than that for the hydrochloric acid process, is still large and amounts to approximately 3.8 tons of waste material per ton of alumina produced, of which nearly 50 percent is water. The pollutants of liquid effluent of major concern are the soluble nitrates such as calcium, magnesium, sodium, potassum, zinc, and lead. Air pollution would consist of dust emissions and gas containing oxides of nitrogen.

Alumina Production	26.76×10^6 Btu/Ton Alumina
Environmental Controls	0.695×10^6 Btu/Ton Alumina

B. Hydrochloric Acid Leaching Process

The hydrochloric acid ion exchange process involves the following steps:

1. The clay is dehydrated, leached with hydrochloric acid, and then settled to separate the residue from the aluminum chloride/iron chloride solution.
2. This solution is then purified with an amine ion exchange system operation to remove the iron chloride, while leaving the aluminum chloride in solution.
3. The aluminum chloride in solution is crystallized from the solution and decomposed to alpha alumina, and the acid value is recovered.

Discharge from this process is large, amounting to approximately 6.7 tons of waste material per ton of alumina, of which 50 percent is water. The pollutants of major concern are the soluble chlorides. This process would generate several waste gas streams containing HCl.

Alumina Production	39.21×10^6 Btu/Ton Alumina
Environmental Controls	0.016×10^6 Btu/Ton Alumina

C. Clay Chlorination (Toth Alumina Process)

The clay chlorination process involves the following steps based on the use of kaolin clays:

1. Ore drying and calcination;
2. Chlorination in which the aluminum, titanium, and iron present in the ore are carried overhead as volatile chlorides;
3. Separation of the chlorides from the aluminum chloride by fractional condensation and distillation; and
4. Separate oxidation of the iron, silicon, and titanium chlorides to their respective oxides for recovery of chlorine for recycle.
5. The aluminum chloride, after separation, is also oxidized to produce alumina and to recover chlorine for recycle.

Because this is a dry process there are no aqueous effluent process streams, except indirect cooling water requirements for cooling of exothermic reactions. Air pollution would consist of CO, CO_2, and some traces of HCl.

Alumina Production	28.59×10^6 Btu/Ton Alumina
Environmental Controls	0.293×10^6 Btu/Ton Alumina

II. ALTERNATIVES TO THE HALL-HEROULT PROCESS

The following are considered as candidate process changes for the production of aluminum which relate strongly to the problem of energy conservation. As stated before, historically the aluminum industry has been located near sources of low-cost power. Within the United States such sources are becoming harder to find. Growth in aluminum production will be slower in the future unless power consumption can be reduced.

A. The Alcoa Chloride Electrolysis Process

The Alcoa chloride electrolysis process involves the following steps:

1. Alumina is converted into aluminum chloride for chlorination in the presence of carbon to form volatile aluminum chloride.
2. The aluminum chloride is in turn purified and fed to the electrolytic cells to produce molten aluminum at the cathode and chlorine at the anode.
3. The chlorine is recycled to the chlorination system.

Unlike the Hall process, the alcoa chloride process eliminates the flouride-containing fluxing agent, and therefore eliminates the flouride emissions. This process does, however, produce a chloride-containing wastewater stream. In addition, a small amount of sodium comes in contact with the water. Air pollution would consist of sulphur emissions from the coker, and exhaust from the HC1 absorption system containing primarily CO, CO_2, and small amounts of HC1.

Aluminum Production	109.2×10^6 Btu/Ton Aluminum
Environmental Controls	0.42×10^6 Btu/Ton Aluminum

B. Application of Titanium Diboride Cathodes

Substitution of titanium diboride cathodes in place of the graphite cathodes presently used in the Hall-Heroult cells would increase electrical conductivity, eliminate corrosion by the electrolytic bath, and therefore increase the life of the cathode to at least four years. Introduction of this type of cathode would reduce the consumption of anode carbon, and therefore petroleum coke and pitch, saving approximately 20 percent of the total energy used to produce aluminum.

The consumption of, and therefore the production of, anode carbon would be slightly less and thus the pollution generated as a result of making anodes would be less. "Off gas" from the anode would be largely CO_2 and CO.

Aluminum Production	151.2×10^6 Btu/Ton Aluminum
Environmental Controls	less than 1% of above

Table B-1 shows a comparison of the energy consumed in each of the alternative processes.

TABLE B-1

COMPARISON OF ALUMINUM PROCESSES

($x10^6$ BTU/Ton Alumina)

	Present Bayer Process	Nitric Acid Leaching Process	Hydrochloric Acid Leaching Process	Clay Chlorination
Clay to Alumina	37.25[B]	26.76[L]	39.21[L]	28.59[L]

($x10^6$ BTU/Ton Aluminum)

	Present Hall-Heroult P-ocess	Alcoa Chloride Electrolysis Process	Application of Titanium Diboride Cathodes
Alumina to Aluminum	168.00[B]	109.2[L]	151.2[L]

B-Batelle Columbus Laboratories, Energy Use Patterns in Metallurgical & Non-metallic Mineral Processing, Phase 4 - Energy Data & Flowcharts -- High Priority Commodities, June 1975.

L-Arthur D. Little, Inc., Environmental Considerations of Selected Energy Conserving Manufacturing Process ... Volume VIII ..., Dec. 1976.

Reference:

Arthur D. Little, Inc. Environmental Considerations of Selected Energy Conserving Manufacturing Process, Volume III, Cambridge, Mass., EPA/600/7-76/034H, December 1976.

APPENDIX C

THERMOMECHANICAL PULPING

The use of Thermomechanical Pulping in the pulp and paper industry has grown notably in recent years. In 1975, Thermomechanical Pulp accounted for 13 percent of the total pulp produced.[1] The technique for Thermomechanical Pulping has been known since the early 30's; however, the recent sharp price increase and shortage of chemical fiber as well as the difficulty and expense of chemical pulping processes meeting Government regulations concerning air and water pollution has made Thermomechanical Pulping much more attractive.

Thermomechanical Pulp is an acceptable substitute for both chemical and groundwood pulp. There is research being done by the paper industry to determine the best ratio mix and conditions for paper production using this method.[11] There have been claims that it is possible to use 100 percent Thermomechanical Pulp for paper production.

Thermomechanical Pulping consists of preheating chips or sawdust then subjecting them to mechanical forces in a single disc or counter rotating refiner under pressure. The wood is subjected to repeated compressions and stress relaxations in the gap between the opposite bars and grooves.

The chips are presteamed above 100° C. Problems with lignin are encountered if this refining is between 120° C and 140° C so the temperature must be controlled. By processing the chips at a controlled elevated temperature the fibers are more completely separated from each other with less fiber damage than in other conventional pulping operating. If Thermomechanical Pulping is carried out at the correct temperature, there is no discoloration and total energy consumption is reduced due to softening of the wood. The production and quality of Thermomechanical Pulp are affected by several variables including temperature, refining consistency, horsepower, the power split between stages and the quality of raw material.

Thermomechanical pulping allows the use of lower grades of species and sawdust, as well as increasing the yield from wood resources by 15 percent. This aspect makes thermomechanical pulping very attractive in situations of shortage of raw materials. Thermomechanical Pulping is a much lower capital investment than chemical pulping. It produces less water pollution, no air pollution and consumes no chemicals.[2]

The quality of Thermomechanical Pulp far exceeds that of the stone groundwood and is superior to refiner pulp produced with equivalent power inputs.[3]

Thermomechanical Pulping, as an alternative to chemical pulping, has higher steam requirements and high energy consumption but makes the overall process of paper production and use more energy efficient.[3] The process increases the efficiency of the use of wood resources of 15 percent, decreases water and air pollution control and consumes no chemicals. The product has a slightly higher freeness, an increase in wet strength of 50 percent, an increase in tensile strength of 40 percent and an increase of 50 percent in the tear factor.[4]

The higher tensile strength and increased strength gives paper a higher rupture energy, a higher wet web strength, better machine runability and fewer pressroom breakdowns.[5]

The extra strength, due to the length of the fibers, may also be reflected in a strong product when using the paper to produce recycled newsprint.

References:

1. Robert R. Peck, "TPM - Major Breakthrough in Mechanical Pulp Manufacture", Pulp and Paper, June 1975, Pages 102-109.

2. John C.W. Evans, "Latest Pulping Methods Spark Interest at CPPA Conference", Pulp and Paper, March 1975, Page 109.

3. Pulp and Paper Staff Report, "Thermo-mechanical Pulping - Reports From Six Mills", Pulp and Paper, August 1975, Pages 56-59.

4. Ibid.

5. George J. Ahlquist, "Weyco Evaluates Thermomechanical Refining at Longview Pilot Plant", Pulp and Paper, June 1975, Pages 56-59.

6. Peck, op. cit.

APPENDIX D

SECTION 1 - METHODOLOGY FOR DETERMINATION OF TRANSPORTATION COSTS

I. Determination of Profit for Centers

A. Buy-back: Price F.O.B. market

Material	Market Price	Buy-back Price	Premium	% by Weight
Aluminum	$760/ton	$340/ton	$420/ton	9.0
Newsprint	40	15	25	77.6
Glass	30	15	15	10.2
Ferrous	0	0	0	3.2

Revenues calculated as:
3.2% (0) + 9% (420) + 77.6% (25) + 10.2% (15) = $58.73/ton

Profit vs TPM ($/month)

TPM	50	100	200	300	400	500
Revenues	$2937	$5873	$11746	$17619	$23492	$29365
Cost	5463	5598	5875	7177	7454	8756
Profit	<$2526>	$ 275	$ 5871	$10442	$16038	$20609

From regression analysis: Profit = TPM (51.47) - $4845
(Correlation = 0.999)

B. Separate Curbside Collection with Aluminum Buy-back (Price F.O.B. Market)

Material	Market Price	Buy-back Price	Premium	% by Weight
Aluminum	$760/ton	$340/ton	$420/ton	9.0
Newsprint	40	0	40	50.5
Glass	30	0	30	32.1
Ferrous	0	0	0	8.4

Revenues calculated as:
8.4% (0) + 9% (420) + 50.5% (40) + 32.1% (30) = $67.63/ton

TPM	100	200	300	400	500	600
Revenues	$6763	$13526	$20289	$27052	$33815	$40578
Cost	7071	10051	12011	14997	17674	20665
Profit	<$ 308>	$ 3475	$ 8278	$12055	$16141	$19913

Regression analysis yields: Profit = TPM (40.82) - $4362
(Correlation = 0.999)

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II. Determination of Transportation Cost:

A. Own transport vehicle

1) Fixed Cost:

Amortization	$996/month
Depreciation	417
Insurance	300
Registration Fees	65
Total	$1778/month

2) Bin requirements (45 cubic yard/ferrous excluded)

9% (3.9 cu. yd. Al/ton) + 77.6% (2.5 cu. yd. Newsprint/ton)
+ 10.2% (1.5 cu. yd. Glass/ton) = 2.44 cu. yd./ton

or

$$2.44 \text{ cu. yd./ton} \times \frac{1 \text{ load}}{45 \text{ cu. yd.}} \approx 0.0543 \text{ loads/ton}$$

3) Variable costs (M = miles roundtrip to market; diesel @$0.50/gallon)

$$\text{Fuel} = \$0.50/\text{gallon} \times \text{TPM} \times .0543 \ \frac{\text{loads}}{\text{ton}} \times \frac{\text{miles/load}}{5 \text{ miles/gallon}}$$

$$\text{Maintenance} = .0543 \ \frac{\text{loads}}{\text{ton}} \times \text{TPM} \times \frac{4 \text{ hrs}}{150 \text{ miles}} \times \frac{\$450}{176 \text{ hrs.}} \times \frac{\text{miles}}{\text{load}}$$

$$\text{Labor} = .0543 \ \frac{\text{loads}}{\text{ton}} \times \text{TPM} \times \frac{4 \text{ hrs.}}{150 \text{ miles}} \times \frac{\$12.50}{\text{hr.}} \times \frac{\text{miles}}{\text{load}}$$

Total variable costs = 0.02723 (TPM) (M)

4) Total Cost for own transportation ($/month)

Total = TPM (M) (0.02723) + $1778

B. Rental truck @ $35/hr.

$$\text{Cost} = .0543 \ \frac{\text{loads}}{\text{ton}} \times \text{TPM} \times \frac{\text{Miles}}{\text{load}} \times \frac{4 \text{ hrs.}}{150 \text{ miles}} \times \frac{\$35}{\text{hr.}}$$

= 0.05068 (TPM) (M)

C. PUC ($/month)

Cost = (TPM) x (Rate @ M)

III. Net Profit (NP) in $/month

A. Own

1) Buy-back: $NP = [51.45\ (TPM) - 4844] - [1778 + (TPM)\ (M)\ (.02723)]$

$= TPM\ (51.45 - .02723\ M) - 6622$

2) Separate Curbside:

$NP = [40.87\ (TPM) - 4362] - [1778 + .02337\ (TPM)\ (M)]$

$= TPM\ (40.87 - .02337\ M) - 6140$

B. Rental

1) Buy-back: $NP = [51.45\ TPM - 4884] - [.05068\ (TPM)\ (M)]$

$= TPM\ (51.45 - .05068\ M) - 4844$

2) Separate Curbside:

$NP = [40.87\ TPM - 4362] - [.04349\ (TPM)\ (M)]$

$= TPM\ (40.87 - .04349\ M) - 4362$

C. PUC

1) Buyback: $NP = [51.45\ TPM - 4844] - [(TPM) \times (RATE)]$

$= TPM\ (51.45 - (RATE)) - 4844$

2) Separate Curbside:

$NP = [40.87\ TPM - 4362] - [(TPM) \times (RATE)]$

$= TPM\ (40.87 - (RATE)) - 4362$

IV. Determination of PUC rates (minimum rates) in $/ton from MRT - 2 Commodity Tariffs (Ferrous by NOS rate)

Rate ($/Ton)

Miles	Aluminum	Newsprint	Glass	Ferrous	Buy-back	Separate
50	$17.10	$ 7.60	$ 3.26	$7.80	$ 7.77	$ 6.62
100	21.60	9.80	5.79	9.42	10.14	8.75
200	28.80	12.90	10.32	12.67	13.66	12.42
300	35.00	15.60	14.99	15.92	16.78	15.83
400	41.40	17.90	19.29	19.16	19.58	18.96
500	46.00	20.40	23.59	22.41	22.38	22.01
600	51.60	22.80	27.89	25.66	25.18	25.11

Rate calculated by (% Ferrous is 0):

% Al (Rate Al) + % Newsprint (Rate Newsprint) + % Glass (Rate Glass)

Minimum Weight loads

Aluminum = 10 tons; Newsprint = 24 tons; Glass = 24 tons

V. Results

A) Best Transportation System (Buy-back)

TPM

Miles	50	100	200	300	400	500
50	<R>	R	R	R	R	R
100	<R>	<R>	R	R	R	R
200	<R>	<R>	R	R	0	0
300	<R>	<R>	R	0	0	0
400	<P>	<P>	0	0	0	0
500	<P>	<P>	0	0	0	0
600	<P>	<P>	0	0	0	0

0 = own vehicle; R = rental; P = PUC Carrier

< > = no profit by any system

B) Best Transportation System (Separate Curbside)

TPM

Miles/TPM	100	200	300	400	500
50	<R>	R	R	R	R
100	<R>	R	R	R	R
200	<R>	R	R	R	R
300	<R>	R	0	0	0
400	<R>	R	0	0	0
500	<R>	0	0	0	0
600	<P>	0	0	0	0

VI. Consumer Transportation Costs

Assumptions:

1) 35 lbs. of recyclable/family-month (FM)
2) 16 MPG for 1978 composite passenger vehicle according to Caltrans. 5 miles (M) roundtrip per family-month
3) $0.65 per gallon of fuel (1978)

Calculations:

$$\frac{5\ \text{M/FM}}{16\ \text{MPG}} \times \frac{\$.65}{\text{gallon}} = \$0.20/\text{FM}$$

$$\frac{\$0.20/\text{FM}}{35\ \text{lbs/FM}} \times \frac{2000\ \text{lbs}}{\text{ton}} \approx \$11.43/\text{ton}$$

$$\frac{\$2000\ \text{lbs/ton}}{\$35\ \text{lbs /FM}} = \frac{57\ \text{FM}}{\text{ton}}$$

VII. Amounts of Recyclables from Residential Garbage

Material	Percent by Weight	Lbs/Capita-Day	Lbs Recyclables/ Capita-Day	Percent Recyclables
Scrap Paper (organic)	64.00	1.427		
Newsprint	8.30	0.185	0.185	43.7
Glass (mixed)	6.10	0.136	0.136	32.1
Corregated Paper	5.10	0.114		
Ferrous	3.80	0.085	0.085	19.9
Aluminum	0.85	0.019	0.019	4.3
Other (plastics, garden refuse)	11.85	0.264		
Total	100.00	2.23	0.425	100.00

Notes:

Generation factor of 2.23 lbs. residential garbage/capita-day in SMSA's (SCS, 1978).

Household for 1978 has 2.67 persons/residence (DOF, 1977).

Heating value of organics (paper and other) @4800 Btu/lb, 40% moisture (SCS)

$$\frac{0.425\ \text{lbs. recyclables}}{\text{capita-day}} \times 2.67\ \frac{\text{persons}}{\text{family}} \times \frac{31\ \text{day}}{\text{month}} \approx 35\ \frac{\text{lbs. recyclables}}{\text{family-month}}$$

VIII. START-UP COSTS[1]

	DROP-OFF CENTER	BUY-BACK CENTER	SEPARATE CURBSIDE SYSTEM	INTEGRATED CURBSIDE SYSTEM
Fixed				
Site	$220	$15,060	$15,060	$12,760
Equipment	150	9,740	8,420	8,420
Canvas	100	500	500	500
Utilities Deposit	-0-	375	375	375
Miscellaneous[2]	30	750	750	750
Insurance	900	3,145	1,910	1,910
	$1,400	$29,570	$27,015	$24,715
Variable[3] (per 100 TPM)				
Advertising and Public Education	$-0-	$ 2,000	$ 2,000	$ 2,000
Collection Equipment	-0-	-0-	1,760	-0-
Insurance	-0-	-0-	1,020	120
	$-0-	$ 2,000	$ 4,780	$ 2,120

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[1] The start-up costs for a capital intensive resource recovery system cannot be determined.

[2] Includes amount for office equipment, supplies, and other items.

[3] It is prudent to have as reserve at least 10% of monthly costs as a reserve for contingencies.

SECTION 2 - RECYCLING CENTERS

I. Community Drop-off Recycling Center

Tons per month	10	20	30	40	50
Site[1]					
Land	Donated				
Paving	Donated				
Utility Shed	$ 100	$ 100	$ 100	$ 100	$ 100
Fence	1000	1000	1000	1000	1000
	$1100	$1100	$1100	$1100	$1100
Equipment[2]					
1½ cu. yd. bins @ $200 each	$1200	$2400	$1800	$2400	$2000
Pallet Jack	420	420	420	420	420
Banding Machine	400	400	400	400	400
	$2020	$3220		$3220	$2820
		Monthly Costs			
Labor[3]					
Yard Employee @ $4.07/hr.	$ -0-	$ 61	$ 122	$ 183	$ 244
Insurance					
General Liability	$ 75	$ 75	$ 75	$ 75	$ 75
Utilities	Donated				
Transportation[4]					
Rental	$ 40	$ 48	$ 66	$ 97	$ 137
Depreciation[5]					
Bins (5 yr.)	$ 20	$ 40	$ 30	$ 40	$ 40
Pallet Jack	7	7	7	7	7
Banding machine	7	7	7	7	7
Site	18	18	18	18	18
	$ 52	$ 72	$ 62	$ 72	$ 65

Tons Per Month	10	20	30	40	50
Debt Service[6]					
Equipment	$ 29	$ 49	$ 39	$ 49	$ 42
Site	9	9	9	9	9
	$ 38	$ 58	$ 48	$ 58	$ 51
Advertisement	$ 15	$ 30	$ 45	$ 60	$ 75
Miscellaneous	10	20	30	40	50
TOTAL MONTHLY COSTS	$ 224	$ 377	$ 462	$ 598	$ 711
Revenues[7]					
Aluminum @ $340	$ 37	$ 75	$ 112	$ 150	$ 187
Newsprint @ $15	92	184	275	367	459
Ferrous	-0-	-0-	-0-	-0-	-0-
Glass @ $15	39	78	117	155	194
TOTAL MONTHLY REVENUES	$ 168	$ 337	$ 504	$ 672	$ 840
Net Revenues	<$ 76>	<$ 40>	$ 42	$ 74	$ 129
Revenue/ton	<$ 7.60>	<$ 2.00>	$ 1.40	$ 1.85	$ 2.58

Profit = TPM (5.24) - $131.40

(Correlation = 0.992, breakeven @ 25.0 TPM)

Notes

1. The length of the fence enclosing the site is 200 linear feet.

2. The number of bins for various levels of throughput relate to vehicle rental.

3. Labor is supplied by part-time help and is based on 1.5 hours processing time per ton of material throughput.

4. The frequency of vehicle rental and the number of bins necessary for a given level of throughput has been correlated to minimize costs. Assumptions in the analysis included: 20 miles roundtrip to market with 10 miles to rental yard, and 2 feet of truck length (8' bed width) per ton of material transported. Densities used for the materials were: Aluminum @ 4.9, Glass @ 1.5, Ferrous @ 2.5, and Newsprint @ 2.5 cu. yd. per ton.

5. The depreciation period for site and equipment is 5 years.

6. Debt service is based on a term of 5 years at 9% interest with 20% down.

7. Revenues are calculated as:

   AL = 1.1% ($340/ton)
   GL = 25.9% ($15/ton)
   Nws = 61.2% ($15/ton)   = $16.81/ton material
   Ferr = 11.8% (-0-)

II. Processing/Buy-back Recycling Center

Tons Per Month	50	100	200	300	400	500
Site[1]						
Land	$15000	$15000	$15000	$15000	$15000	$15000
Office Building	11500	11500	11500	11500	11500	11500
Paving	42500	42500	42500	42500	42500	42500
Fence	6300	6300	6300	6300	6300	6300
Total	$75300	$75300	$75300	$75300	$75300	$75300
Equipment[2]						
4/45 cu yd bins	$10000	$10000	$10000	$10000	$10000	$10000
2/Scales	6000	6000	6000	6000	6000	6000
Forklift	20000	20000	20000	20000	20000	20000
Can Processor	9100	9100	9100	9100	9100	9100
Magnetic Separator	2400	2400	2400	2400	2400	2400
6/1½ yd. bins	1200	1200	1200	1200	1200	1200
Total	$48700	$48700	$48700	$48700	$48700	$48700
Monthly Costs						
Labor[3]						
Yard Employee/ Weighmaster	$ 1025	$ 1025	$ 1025	$ 2050	$ 2050	$ 3075
Office Employee	715	715	715	715	715	715
Manager	1160	1160	1160	1160	1160	1160
Total	$ 2900	$ 2900	$ 2900	$ 3925	$ 3925	$ 4950
Insurance[4]						
Auto Liability & Physical Damage	$ 78	$ 78	$ 78	$ 78	$ 78	$ 78
General Liability	75	75	75	75	75	75
Property	95	95	95	95	95	95
Bonds	14	14	14	14	14	14
Total	$ 262	$ 262	$ 262	$ 262	$ 262	$ 262

TPM	50	100	200	300	400	500
Utilities[5]						
Phone	$ 28	$ 30	$ 35	$ 40	$ 45	$ 50
Gas	10	10	10	10	10	10
Electric	43	50	65	80	95	110
Water & Sewer	25	25	25	25	25	25
Total	$ 106	$ 115	$ 135	$ 155	$ 175	$ 195
Maintenance[6]						
Forklift	$ 7	$ 10	$ 20	$ 30	$ 40	$ 50
Can Processor	3	5	10	15	20	25
Mag. Separator	1	2	4	6	8	10
45 cu yd bins	5	10	20	30	40	50
Total	$ 16	$ 27	$ 54	$ 81	$ 108	$ 135
Depreciation[7]						
1½ cu yd bins (5 yr)	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
46 cu yd bins (10 yr)	83	83	83	83	83	83
Forklift Can Processor Mag. Separator Scale	208	208	208	208	208	208
Site (20 yr)	251	251	251	251	251	251
Total	$ 562	$ 562	$ 562	$ 562	$ 562	$ 562
Debt Service						
Equipment (5 yr)	$ 809	$ 809	$ 809	$ 809	$ 809	$ 809
Site (20 yr)	542	542	542	542	542	542
Total	$ 1351	$1351	$1351	$1351	$1351	$1351

TPM	50	100	200	300	400	500
Property[8] Taxes	$ 121	$ 121	$ 121	$ 121	$ 121	$ 121
Advertisement[8]	110	220	440	660	880	1100
Miscellaneous	35	40	50	60	70	80
TOTAL MONTHLY COSTS	$5463	$5598	$5875	$7177	$7454	$8756

Revenues

Aluminum @ $300	$1350	$2700	$5400	$8100	$10800	$13500
Newspaper @ $20.	$ 776	1552	3104	4656	6208	7760
Glass @$3	$ 15	31	61	92	122	153
Ferrous	$ -0-	-0-	-0-	-0-	-0-	-0-
TOTAL MONTHLY REVENUES	$2141	$4283	$8565	$12848	$17130	$21413
Net Revenues	<$3322>	<$1315>	$2690	$5671	$ 9676	$12657
Revenues/ Ton	<$66.44>	<$13.15>	$13.45	$18.90	$24.19	$25.31

Profit = TPM (35.57) - $4845

(Correlation = 0.999; breakeven @ 136.2 TPM)

1. 1^+ acre parcel of land in light commercial semi-isolated area. Cost figure quite variable depending upon geographical location. Building 400 sq. ft., 830 feet acre perimeter @ $7.45 per linear foot for 6' slatted fencing. Paving includes, 2914 sq. ft. concrete slab and asphalt on remaining area, all heavy duty. Local builder's quotes.

2. 45 cu. yd bins @ $2500/bin; digital scales; can processor and mag. separation blower. Quote from local manufacturer. 1.5 cu. yd. steel bins @ $200/bin roller type.

3. Yard employee/weightmaster @ $5.00/hr.
Office employee @ $4.00/hr.
Manager @ $6.00/hr.
The wage rate used to compute monthly costs include coverage for workman's compensation, social security, and unemployment.

4. Rates quoted by independent insurance agent for Northern California. Assumes good driving record by employees. Bond is weighmaster's bond @ $14/month.

5. Utilities calculated in part from information regarding a local recycler which processes 250 TPM and from local utility quotes.

6. Estimated values.

7. Full price depreciated over 5, 10, 15, and 20 years.

8. Average statewide rate including existing bond indebtedness.

III. Separate Curbside Collection System

Tons per Month	100	200	300	400	500	600
Site[1]						
Land	$15000	$15000	$15000	$15000	$15000	$15000
Office Building	11500	11500	11500	11500	11500	11500
Paving	42500	42500	42500	42500	42500	42500
Fence	6300	6300	6300	6300	6300	6300
Total	$75300	$75300	$75300	$75300	$75300	$75300
Fixed Equipment[1]						
4/45 cu yd bins	$10000	$10000	$10000	$10000	$10000	$10000
Scale	3000	3000	3000	3000	3000	3000
Forklift	20000	20000	20000	20000	20000	20000
Can Processor	9100	9100	9100	9100	9100	9100
Total	$42100	$42100	$42100	$42100	$42100	$42100
Variable Equipment[2]						
3/4 ton pickup @ $6800 each	$ 6800	$13600	$20400	$27200	$34000	$40800
Flatbed Trailer @ $1200 each	1200	2400	3600	4800	6000	7200
Trailer bins @ $200 each	800	1600	2400	3200	4000	4800
Total	$ 8800	$17600	$26400	$35200	$44000	$52800
		Monthly Costs				
Labor[3]						
Route Driver $6.22/hr.	$ 1095	$ 2190	$ 3285	$ 4380	$ 5475	$ 6570
Yard Employee $5.82/hr.	1025	2050	2050	3075	3075	4100
Office Employee $4.07/hr.	715	715	715	715	1430	1430
Manager $6.60/hr.	1160	1160	1160	1160	1160	1160
Total	$ 3995	$ 6115	$ 7210	$ 9330	$11140	$13260

TPM	100	200	300	400	500	600
Insurance[1]						
Auto Liability & Phys. Damage	$ 78	$ 156	$ 234	$ 312	$ 390	$ 468
General Liability	75	75	75	75	75	75
Property	84	89	97	107	119	134
Total	$ 237	$ 320	$ 406	$ 494	$ 584	$ 677
Utilities[1]						
Telephone	$ 30	$ 35	$ 40	$ 45	$ 50	$ 55
Gas	10	10	10	10	10	10
Electric	50	65	80	95	110	125
Water & Sewer	25	25	25	25	25	25
Total	$ 115	$ 135	$ 155	$ 175	$ 195	$ 215
Gasoline[4]	$ 170	$ 340	$ 510	$ 680	$ 850	$1020
Maintenance						
Trucks	$ 20	$ 40	$ 60	$ 80	$ 100	$ 120
Forklift	15	30	45	60	75	90
Can Processor	10	20	30	40	50	60
45 cu yd bins	10	20	30	40	50	60
Trailers	5	10	15	20	25	30
Total	$ 60	$ 120	$ 180	$ 240	$ 300	$ 360
Depreciation[1]						
Trucks Trailers (5 yr) 1½ cu yd bins	$ 147	$ 293	$ 440	$ 587	$ 733	$ 880
40 cu yd bins (10 yr)	83	83	83	83	83	83
Forklift (15 yr) Can Processor Scale	178	178	178	178	178	178
Site (20 yr)	251	251	251	251	251	251
Total	$ 659	$ 805	$ 952	$1099	$1245	$1392

TPM	100	200	300	400	500	600
Debt Service						
Equipment (5 yr)	$ 845	$ 991	$1138	$1284	$1430	$1576
Site (20 yr)	542	542	542	542	542	542
Total	$1387	$1533	$1680	$1826	$1972	$2118
Advertisement[1]	$ 200	$ 400	$ 600	$ 800	$1000	$1200
Property Taxes[1]	$ 114	$ 114	$ 114	$ 114	$ 114	$ 114
Miscellaneous	$ 50	$ 60	$ 70	$ 80	$ 90	$ 100
TOTAL MONTHLY COSTS	$6987	$9942	$11877	$14838	$17490	$20456
Revenues						
Aluminum @ $640	$ 832	$1664	$2496	$ 3328	$ 4160	$ 4992
Newspaper @ $35	1918	3836	5751	7672	9590	11508
Ferrous	-0-	-0-	-0-	-0-	-0-	-0-
Glass @ $18	626	1253	1879	2506	3132	3758
TOTAL MONTHLY REVENUES	$3376	$6653	$10129	$13506	$16882	$20258
Net Revenues	<$3611>	<$3289>	<$1748>	<$1332>	<$ 608>	<$ 198>
Revenue/ton	<$36.11>	<$16.45>	<$5.83>	<$3.33>	<$1.22>	<$0.33>

Profit = TPM (7.30) - $4354

(Correlation = 0.979, breakeven @ 596 TPM)

It can be seen by inspection, however, that the breakeven point is just over 600 tons/month.

Separate Curbside Collection System with Aluminum Buy-Back

Tons Per Month	100	200	300	400	500	600
Total Monthly Costs[5]	$7071	$10051	$12011	$14997	$17624	$20665
Revenues						
Aluminum @ $300	$2700	$5400	$8100	$10800	$13500	$16200
Newspaper @ $35	1768	3535	5303	7070	8838	10605
Ferrous	-0-	-0-	-0-	-0-	-0-	-0-
Glass @ $18	578	1156	1733	2311	2889	3467
Total	$5046	$10091	$15136	$20181	$25227	$30272
Net Revenue	<$2025>	$ 40	$ 3125	$ 5184	$ 7553	$ 9607
Revenue/ton	<$20.25>	$ 0.20	$10.42	$12.96	$15.11	$16.01

Profit = TPM (23.65) - $4362

(Correlation = 0.998); breakeven @ 184 TPM)

1. Please see notes on Processing/Buy-back Center under similar headings. Can Processor includes a magnetic separator.
2. Variable equipment is curbside collection equipment. Quotes are from local retail distributor and manufacturer.
3. Please see similar heading under Processing/Buy-back Center. Route driver @ $6.00/hr. + fringe. Processing time @ 1 hr/ton.
4. Each vehicle goes 75 miles/day @ 7 miles/gallon for 22 days/month plus 30 gallons/month for forklift. There is one truck/tractor for every 100 TPM. Gasoline price, 1978, @ $0.65/gallon.
5. Cost includes additional equipment debt service for another magnetic separator, scale, etc.

IV. Integrated Collection System

Tons Per Month	100	200	300	400	500	600
Site[1]						
Land	\$15000	\$15000	\$15000	\$15000	\$15000	\$15000
Paving	42500	42500	42500	42500	42500	42500
Fence	6300	6300	6300	6300	6300	6300
Total	\$63800	\$63800	\$63800	\$63800	\$63800	\$63800
Equipment[1]						
4/45 cu yd bins	\$10000	\$10000	\$10000	\$10000	\$10000	\$10000
Scale	3000	3000	3000	3000	3000	3000
Forklift	20000	20000	20000	20000	20000	20000
Can Processor	9100	9100	9100	9100	9100	9100
Total	\$42100	\$42100	\$42100	\$42100	\$42100	\$42100

Monthly Costs

	100	200	300	400	500	600
Labor[2]						
Yard Employee \$5.82 hr.	\$ 1024	\$ 2050	\$ 2050	\$ 3075	\$ 3075	\$ 4100
Office Employee \$4.07 hr.	715	715	715	715	1430	1430
Manager \$6.60/hr	1160	1160	1160	1160	1160	1160
Total	\$ 2899	\$3925	\$3925	\$4950	\$5665	\$6690
Insurance[2]						
General Liability	\$ 75	\$ 75	\$ 75	\$ 75	\$ 75	\$ 75
Property	84	89	97	107	118	134
Total	\$ 159	\$ 164	\$ 172	\$ 182	\$ 193	\$ 209
Utilities[2]						
Telephone	\$ 30	\$ 35	\$ 40	\$ 45	\$ 50	\$ 55
Electric	50	65	80	95	110	125
Water & Sewer	25	25	25	25	25	25
Total	\$ 105	\$ 125	\$ 145	\$ 165	\$ 185	\$ 205

TPM	100	200	300	400	500	600
Maintenance[1]						
Forklift	$ 15	$ 30	$ 45	$ 60	$ 75	$ 90
Can Processor	10	20	30	40	50	60
45 cu yd bins	10	20	30	40	50	60
Total	$ 35	$ 70	$ 105	$ 140	$ 175	$ 210
Depreciation[3]						
45 cu yd bins (10 yr)	$ 83	$ 83	$ 83	$ 83	$ 83	$ 83
Forklift Compressor (15 yr) Scale	178	178	178	178	178	178
Site (20 yr)	251	251	251	251	251	251
Total	$ 512	$ 512	$ 512	$ 512	$ 512	$ 512
Debt Service						
Equipment (5 yr)	$ 699	$ 699	$ 699	$ 699	$ 699	$ 699
Site (20 yr)	459	459	459	459	459	459
Total	$ 1158	$ 1158	$ 1158	$ 1158	$ 1158	$ 1158
Advertisement[1]	$ 200	$ 400	$ 600	$ 800	$ 1000	$ 1200
Property Tax[1]	$ 103	$ 103	$ 103	$ 103	$ 103	$ 103
Miscellaneous	$ 50	$ 60	$ 70	$ 80	$ 90	$ 100
TOTAL MONTHLY COSTS	$ 5221	$ 6517	$ 6790	$ 8090	$ 9081	$10387
Revenues						
Aluminum @ $640	$ 832	$ 1664	$ 2496	$ 3328	$ 4160	$4992
Newspaper @ $35	1917	3836	5754	7672	9590	11508
Ferrous	-0-	-0-	-0-	-0-	-0-	-0-
Glass @ $18	626	1253	1879	2506	3132	3758
Total	$ 3375	$ 6753	$10129	$13506	$16882	$20258

TPM	100	200	300	400	500	600
Tipping Fee Reduction	300	600	900	1200	1500	1800
TOTAL MONTHLY REVENUE	$3675	$7353	$11029	$14706	$18382	$22058
Net Revenue	$<1546>	836	4256	6616	9301	11671
Revenue/Ton	<$15.46>	$4.18	$14.13	$16.54	$18.60	$19.45

Profit = TPM (26.81) - $4199
(Correlation of 0.999 breakeven @ 157 TPM)

Integrated Collection System with Aluminum Buy-Back

Tons Per Month	100	200	300	400	500	600
TOTAL MONTHLY COSTS[4]	$5305	$6626	$6924	$8229	$9265	$10596
Revenues						
Aluminum @ $300	$ 2700	$ 5400	$ 8100	$10800	$13500	$16200
Newspaper @$35	1768	3536	5303	7070	8838	10605
Ferrous	-0-	-0-	-0-	-0-	-0-	-0-
Glass @ $18	578	1156	1733	2311	2889	3467
Sub-Total	$ 5046	$10092	$15136	$20181	$25227	$30272
Tipping Fee Reduction	$ 300	$ 600	$ 900	$ 1200	$ 1500	$ 1800
TOTAL MONTHLY REVENUES	$ 5346	$10692	$16036	$21381	$26727	$32072
Net Revenues	$ 41	$ 4066	$ 9112	$13152	$17464	$21476
Revenue/Ton	$ 0.41	$20.33	$30.37	$32.88	$34.92	$35.79

Profit = TPM (43.26) - $4255
(Correlation = 0.999; breakeven @98 TPM)

1. Please see Processing/Buy-back description under similar heading. Office building is donated and land is adjacent to collection vehicle yard.
2. Labor, Insurance, Utilities, and Maintenance same as Separate Curbside Collection excluding driver labor costs, auto insurance costs, gas utility and truck and trailer maintenance costs.
3. Depreciation over 5, 10, 15, and 20 years @ full price.
4. Cost includes additional equipment debt service for another magnetic separator, scale, etc.

APPENDIX E

SURVEY SCREENING FORM SAMPLE
(Aluminum Beverage Cans)

DESCRIPTION OF SURVEY

A. WHO IS THE SURVEY BEING CONDUCTED FOR?

Solid Waste Management Board of the State of California

B. PURPOSES OF STUDY

1. Find ways to reduce the quantity of solid waste going into landfills in California.
2. Provide additional raw material supplies to industry (to supplement existing virgin supplies).

C. WHO SHOULD ANSWER QUESTIONNAIRE?

1. It would be appreciated if you would have the person within your company who is most responsible for deciding on the use of recovered materials complete this questionnaire.
2. It is vital that we receive answers from your company regardless of whether your firm has an interest or has no interest in purchasing the recovered materials.

D. CONFIDENTIALITY

All information you provide will be considered proprietary and confidential and will not be released outside the SSWMB without your company's written approval.

E. HOW TO ANSWER

1. Read the description of material(s) completely before answering any questions. Material description(s) can be modified as needed to more closely meet your requirements. So, in answering questions, please remember that modifications are possible.
2. Some companies will receive 1 questionnaire since they are concerned with only 1 recovered material. Other companies will receive 2 or more questionnaires, each dealing with a different material. If you receive 2 or more questionnaires, please answer each one separately. We realize that this may be a lot of work, but the information you provide is essential to accomplishing this project's objectives and will directly benefit you and the industry in general by providing alternative raw material supplies.
3. Answer questions for your plant only. If you feel we should also contact another plant or if you can answer for another plant within your company, we will send out an additional questionnaire.
4. Some questions pertain only to manufacturers, others to dealers. Those that are to be answered only by 1 group are marked accordingly.
5. Return questionnaire(s) in the enclosed postage paid envelope.

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DESCRIPTION OF ALUMINUM BEVERAGE CANS
(from a hand separation system)

This description summarizes the material make-up, delivered packaging, price, supplier, and delivery for aluminum beverage cans (hand separated). In answering the attached questionnaire about aluminum beverage cans (hand separated), please remember that modifications can be made to the following description so that the material more closely meets your requirements.

MATERIAL

- The material will consist of decorated or painted aluminum (alloy) beverage cans to be recovered from household and commercial waste.
- Magnetic separation will remove any iron or steel.
- The material will be sorted and inspected by hand to insure that only cans are included.
- Contaminants of all types, including dirt or grease, will not exceed 2½% of the total weight.
- The cans will not be corroded (since they will be recovered within a few days after arrival at the waste disposal site.)

DELIVERED PACKAGING

- The material will be delivered loose or in lightly compressed bales which will fall apart of their own accord when they are unstrapped.
- The material will be delivered in dry condition.

PRICE

- Price will equal the lowest competitive price of a similar quality of recycled cans (including delivery to any California location.

SUPPLIER

- The supplier will be one or more private contractors in the San Francisco Bay Area.

RELIABLE DELIVERY

- If you desire, the material can be provided under a contract guaranteeing delivery (and acceptance by you) of a specified quantity on a consistent delivery schedule.

QUESTIONNAIRE: ALUMINUM BEVERAGE CANS

1. Which one of the following statements best describes your company's experience with aluminum beverage cans during the past 12 months? (CIRCLE ONE)

   a. Regularly purchased/used
   b. Occasionally purchased/used
   c. Seldom purchased/used
   d. Tested as an experiment
   e. Seen, but never used it
   f. Heard of it, but never used it
   g. Never heard of it
   h. Don't know

> IF YOU ANSWERED a, b, or c in Question 1, PLEASE SKIP TO QUESTION 3. IF YOU ANSWERED d, e, f, g, or h, PLEASE ANSWER QUESTION 2 AND THEN SKIP TO QUESTION 4.

2. Why have you never purchased/used aluminum beverage cans?

   ____

3. Please describe your company's purchases (or use) of aluminum beverage cans during the past 12 months by answering the following questions (a-h).

   a. Please describe the aluminum beverage cans purchased/used by your plant/facility.

   ____

   ____

   ____

   b. (FOR MANUFACTURERS ONLY) What quantity of recyclable aluminum beverage cans was produced in-house in the past 12 months? ____________tons

   c. What total quantity of aluminum beverage cans was purchased during the last 12 months? ____________tons

   d. Approximately what price per ton did you pay for aluminum beverage cans during the past 12 months?

   High $________ Average $________ Low $________

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e. Check all of the sources from which you purchased aluminum beverage cans during the past 12 months. Then circle the one from which you purchased the most aluminum beverage cans.

- ( ) Direct from public
- ( ) Direct from landfill
- ( ) Neighborhood recycling center
- ( ) From scavenger/junkman
- ( ) Waste/refuse hauler
- ( ) Scrap dealer
- ( ) Dealer-processor
- ( ) Broker
- ( ) Other: ________________
- ( ) ________________

f. On the average, how many miles from your facility was the original source of the aluminum beverage cans you bought? ______ miles

g. Were the aluminum beverage cans bought under a contract or as needed?

( ) As needed ( ) Contract. If on contract, how long is the contract in force?

______ Years ______ Months

Type of Contract? ________________

h. Please describe any problems with the supplier or the aluminum beverage cans you are now buying.

____

4. Considering the aluminum beverage cans as described in this survey, and thinking ahead 2 to 3 years, how likely would your company be to purchase some quantity? (NOTE: Modifications to description are possible)

- ( ) Definitely would buy
- ( ) Would consider buying/try to negotiate a deal
- ( ) Would be unlikely to buy but would listen to your story
- ( ) Definitely would not buy even if we could significantly change the material description (ANSWER QUESTION 4a AND THEN SKIP TO QUESTION 15)
- ( ) Don't know/uncertain

4a. (FOR THOSE WHO DEFINITELY WOULD NOT BUY) Why do you feel that way?

____

____

5. What do you believe is the most important advantage of buying the aluminum beverage cans as described in this survey?

____

6. What do you believe is the most important disadvantage of buying the aluminum beverage cans as described in this survey?

____

7. Please describe what changes are needed in the description of the aluminum beverage cans to make it more likely for your company to be willing to buy or at least enter into negotiations to buy such material. If no changes are needed, please write in "none."

a. Changes in physical make-up of material: ______________________________

b. Changes in chemical content: ______________________________

c. Changes in packaging: ______________________________

d. Changes in delivery: ______________________________

e. Other changes: ______________________________

8. If the aluminum beverage cans as described in this survey were offered today, what would you expect the price per ton to be on a delivered basis? How about in 2 or 3 years?

Price today: $________ Price in 2-3 years: $________

9. Thinking ahead 2 to 3 years about the aluminum beverage cans described (and with modifications to meet your requirements):

a. How many tons might your company location buy annually? ____________ tons

b. What would the average quantity per shipment be? ____________ tons

c. Approximately what percent of your total material needs would this quantity of aluminum beverage cans represent? ________%

10. In developing an agreement to purchase aluminum beverage cans as described in this survey, it's often necessary to have certain provisions in a contract to protect both the buyer and the seller. Assuming your company would be willing to enter into some form of agreement, how would you feel about the following issues:

a. What commitments or guarantees would you need to have from the seller (recovery project) or the government before entering into serious price and volume negotiations or making a commitment to purchase?

____

____

b. If your company entered into a contract to purchase aluminum beverage cans, which contractual time period would be most preferable?

( ) Only on an as needed basis; no contract

( ) Less than 6 months

( ) 6 months to 1 year

( ) One year

( ) 2-5 years

( ) 6-10 years

( ) 11-20 years

( ) More than 20 years

c. How likely would your company be to accept a floor price contract, that is where you as the buyer agree to pay a minimum price per unit for aluminum beverage cans over a given time period, usually several years?

Extremely Likely	Somewhat Likely	Somewhat Unlikely	Extremely Unlikely	Don't Know
( )	( )	( )	( )	( )

Why is that?____

____

d. To insure financeability of resource recovery facilities, many recovery plants across the country have used "take or pay" contracts with their customers. This is where the buyer must "take" (buy) the recovered product or pay the cost for its disposal for a period of time equivalent to the term of the debt on the recovery facility. How likely would your company be to accept a "take or pay" contract to insure a guaranteed supply of aluminum beverage cans?

Extremely Likely	Somewhat Likely	Somewhat Unlikely	Extremely Unlikely	Don't Know
( )	( )	( )	( )	( )

Why is that?____

____

e. What types of discounts might your company expect to be included in a contract to buy aluminum beverage cans, e.g., quantity, cash, etc.?

____

11. If you were to buy aluminum beverage cans, would your company prefer dealing with a recovery plant which was:

( ) Completely private enterprise (owned and operated)

( ) Publicly owned but privately operated

( ) Publicly owned and operated

( ) Other:____________________

____

12. In what ways should government be involved in the recovery of aluminum beverage cans for resale to industry?

____

____

13. Assuming that you were to purchase the aluminum beverage cans described in this study, check all of the sources from which you would probably buy. Then circle the one from which you would prefer to do most of your business.

( ) Direct from public
( ) Direct from landfill
( ) Neighborhood recycling center
( ) From scavenger/junkman
( ) Waste/refuse hauler
( ) Scrap dealer
( ) Dealer-processor
( ) Broker
( ) Other: ____________________
____

13a. What is the main reason for your preferring that source?

____

____

14. If you were interested in finding more information on the availability and prices of aluminum beverage cans, what key sources would you seek out?

____

____

15. Your primary business activity:

( ) Primary aluminum manufacturer
( ) Secondary aluminum manufacturer (e.g., ingots)
( ) Aluminum foundry
( ) Aluminum scrap dealer
( ) Aluminum scrap exporter
( ) Other (specify type) ____________________

16. Primary product(s) manufactured: ____________________

17. How many employees are there at your facility?

Total________ Production workers________

18. Your facility's sales volume: $_______________

19. (FOR ALUMINUM SCRAP DEALERS, BROKERS, DISTRIBUTORS ONLY) Please check all of those groups below to which you now sell aluminum beverage cans. Then circle the one group which absorbs most of your sales.

( ) Primary aluminum manufacturer

( ) Secondary aluminum manufacturer (e.g., ingots)

( ) Aluminum foundry

( ) Aluminum scrap exporter

( ) Other (specify type): ____

20. Your name:____________________________ 21. Title:____________________

22. Company:______________________ 23. Address:__________________________

24. City:_______________ 25. County:___________ 26. Phone: (   )______________

THANK YOU VERY MUCH FOR YOUR ASSISTANCE

APPENDIX F

WORKPLAN

Reduction of Energy Consumption in Product Manufacture Through Increased Participation in Recycling

GOAL: Reduce energy consumption in processes for the manufacture of aluminum, glass and paper products by increasing the availability of recycled aluminum, glass and paper products.

OBJECTIVES:

I. Increase procurement of recycled aluminum, glass and paper products by product manufacturers.

II. Increase public agency procurement of products wholly or partially derived from recycled materials.

III. Increase volume of recycled aluminum, glass and paper products delivered to market from recycling centers and public agencies.

IV. Establish a data base describing the amount and character of recycled aluminum, glass and paper products available to manufacturers by July 1, 1980.

The following methods will be used to achieve the above objectives. Detailed approaches to each task will be developed at the start of the project.

MANUFACTURING INCENTIVES:

Task I. Develop background information to support programs providing tax incentives or the use of recycled materials in product manufacture, and require the use of recycled materials in the manufacture of specified new products.

PUBLIC AGENCY INVOLVEMENT:

Task II. Develop background information to support programs to stimulate public agency procurement of products wholly or partially derived from recycled materials, and their participation in programs for the recycling of aluminum, glass and paper products. Develop and implement programs to increase public agency participation in recycling programs and reduction of disincentives or constraints to procurement of products wholly or partially derived from recycled materials.

CLEARINGHOUSE FUNCTION:

Task III. Implement a State clearinghouse function in the State Solid Waste Management Board to aid in marketing through development of market forecasting models, preparation of model contracts, and listing of markets, recycling centers, agency and industry contracts.

MONITORING METHODS:

Task IV. Develop uniform cost-accounting and market reporting mechanisms for monitoring of recycling centers. Develop an electronic data processing system for cost, volume, materials and marketing analysis of selected recycling centers, so that the information thereby obtained may be used to screen proposals for recycling centers, to aid in preparing recycling center proposals, and to develop marketing forecasting models for recycled aluminum, glass and paper products.

REPORTS AND SCHEDULE

The SSWMB will work closely with the Commission on this project. As part of this cooperation, quarterly progress reports, detailing the actions that have been taken to date, will be submitted to the Commission project manager. These reports will be submitted according to the following schedule:

First Quarterly Report:	December 1, 1979
Second Quarterly Report:	March 1, 1980
Third Quarterly Report:	June 1, 1980

At the conclusion of the project, a final report will be prepared. It will describe in detail the actions taken under this contract, and will include as attachments copies of any additional reports or analyses done as part of this program. It will also include the following evaluations:

I. Assessment of whether increased volume of recycled aluminum, glass, and paper has been procured by manufacturers of these products (aluminum foundries, glass manufacturers, paper mills, etc.). This assessment will include both estimates of the total volume of materials procured, as well as a comparison of the percentage volume of recycled materials compared with virgin material inputs or manufacturer outputs, as applicable.

II. Assessment of the increases of participation in recycling programs by public agencies. This will include a discussion of the source separation and "high technology" waste processing plant programs initiated or expanded. The purpose of this latter assessment is to obtain an indication of the impact of the report and recommendations developed under Phase I of this project (the Energy Analysis of Secondary Material Use in Product Manufacture report).

III. Assessment of the changes in governmental procurement practices which are designed to increase the usage of recycled materials in products being produced by manufacturers.

IV. Assessment of the performance of selected recycling centers and public agencies in delivery of recycled materials to market, including the impact of the work done under Task III.

V. Description of the market reporting and model recycling center parameters developed under Task IV, with an analysis of the impact of the resulting information in the design of recycling programs, the efficiency of operation of recycling centers, and the selection of projects to be funded under the SB 650 and 651 (as amended) recycling center grant program.

These evaluations will also include a determination of the energy savings from the program's implementation (see the Energy Savings section, presented below). This report will be submitted to the Energy Commission by June 30, 1980.

ENERGY SAVINGS IMPACT

The SSWMB believes the following energy savings at a minimum can be achieved through the combination of the SB 650 grants program and the implementation of this program in calendar year 1980:

- Current level of recycling: 85,000 tons
- Level of recycling with the SB 650 grants program: 104,000 tons
- Level of recycling with the SB 650 grants program and with the market and recycling center operation incentives program: 142,000 tons
- Net increase due to SB 650 and this program: 0.59×10^{12} Btu's

The actual energy savings will be calculated from recycled material volumes information supplied by the SB 650 funded recycling programs, users of the market information clearinghouse, and through direct SSWMB staff contact with those programs which do not use directly these services. These volumes will then be compared to existing volume information compiled by the Board in its preparation of its State Solid Waste Resource Recovery Program report (June, 1976), and the information supplied to it through the SB 650 grant application process. The net increase in the volumes of materials recycled, by type (steel, aluminum, glass and paper), will be multiplied by the factors of energy savings per ton of raw material replaced calculated in the previous mentioned report.

GLOSSARY

ALUMINA: Aluminum Oxide ($A1_2 03$), an intermediate product in the production of aluminum.

ALLOYING: To reduce the purity of a metal by mixing with an alloy such as zinc or magnesium.

ANODE: In aluminum production, the positively-charged carbon terminal in the reduction cell or pot. Oxygen is attracted to the anode where it combines with carbon plus any impurities, such as sulfur, which may be present. The anode is consumed by this process and must be replaced periodically.

BACK-END SYSTEMS: The portion of a high-tech facility where fuel is produced from the combustible component of garbage or where the combustibles are burned to produce energy.

BRITISH THERMAL UNIT (BTU): The mean British Thermal Unit is 1/180 of the heat required to raise the temperature of one pound of water from 32°F at a constant atmospheric pressure. It is about equal to the quantity of heat required to raise one pound of water 1°F. A Btu is essentially 252 calories.

BUSBAR: A heavy metal conductor, usually copper, for high amperae electricity.

BUY-BACK/PROCESSING CENTER: A location where materials are purchased from public and subsequently processed for delivery to market.

CALCINING: Roasting of ore in an oxidizing atmosphere, usually to expel sulfur or carbon dioxide.

CAPITAL-INTENSIVE SYSTEMS: A term for high-tech energy recovery systems.

CATHODE: In aluminum production, the negatively-charged terminal of the reduction cell to which the aluminum migrates. The terminal consists of the carbon lining which makes up the bottom of the cell.

CHARGING: Feeding raw material into an apparatus; for example, into a furnace, for treatment or conversion.

CHEMICAL PULP (KRAFT): Pulp that is produced by breaking down wood into fibers by the use of chemicals.

CHLORINE: Gaseous chemical used in pulp bleaching.

CHLORINE DIOXIDE: Chemical used in the bleaching of pulp.

COKE, PETROLEUM: The solid carbonaceous residue remaining as the final product of the condensation processes in cracking. It consists of highly polycyclic aromatic hydrocarbons very poor in hydrogen. It is used extensively in metallurgical processes. Calcination of petroleum coke can yield almost pure carbon or artificial graphite suitable for production of electrodes, motor brushes, dry cells, etc.

COMMUNITY DROP-OFF RECYCLING CENTER: An unattended location run by a non-profit service organization where the public deposits usually less than 50 TPM of recyclable materials.

CONVECTION: The transmission of heat by circulation of a liquid gas. Convection may be natural or forced.

CRYOLITE: Sodium aluminum flouride (Na_3A1F_6) used as an electrolyte in smelting of alumina to provide aluminum.

CULLET: A term used by the glass container manufacturers referring to glass that is broken up to be reintroduced into a glass furnace to produce containers.

DEINKED: Processing recycled newspaper in a chemical process which removes the ink.

DROSS: The scum that forms on the surface of molten metal, usually due to oxidation, but occasionally due to the rising of impurities to the surface.

ELECTROLYTE: A solution which conducts electricity.

ENERGY RECOVERY: An industrial process whereby fuel is produced from the combustible components of garbage.

FLINT GLASS: Clear glass.

FLUX: 1. In chemistry and metallurgy, a substance that promotes the fusing of minerals or metals or prevents the formation of oxides.

2. A substance added to a solid to increase its fusibility.

3. A substance to reduce melting temperature.

4. Any chemical or rock added to an ore to assist in its reduction by heat, such as limestone with iron ore in a blast furnace.

FRONT-END SYSTEM: An array of processing hardware in which solid wastes are subjected to physical processes designed to change their composition and consistency. Front-end systems include hand-sorting, shredding or milling, air classification, various processes for magnetically removing ferrous metals and aluminum, removal and sorting of glass, and wet and dry fiber recovery systems.

HIGH-TECH SYSTEM: A resource recovery facility where non-combustibles, many of which are recyclables, are separated from combustibles by mechanical means, and a fuel is produced from the combustibles. High-tech systems, as distinguished from labor-intensive low-tech systems, are also termed capital-intensive resource recovery systems.

HOME SCRAP: Scrap generated in the mill.

HYDROSULFITES: Salts of hydrosulfurous acid used in the paper making process to bleach pulp.

HYPOCHLORITE: Chemical used in the bleaching of pulp.

IN-HOUSE CULLET: Cullet produced at a glass manufacturing facility that is reintroduced to the furnace. Usually, in-house cullet, averaging 10 percent of a batch, results from problems encountered in the furnace, the mixture, or container fabrication.

INTEGRATED CURBSIDE COLLECTION: A residential collection service of source separated recyclable materials and garbage combined.

KILN: A furnace in which the heating operations do not involve fusion. Kilns are most frequently used for calcining, and free access of air is permitted. The raw materials may be heated by the combustion of solid fuel with which they are mixed, but more usually they are heated by gas or the waste heat from other furnaces.

LABOR-INTENSIVE SYSTEM: A resource recovery system where recyclables are separated without sophisticated machinery; e.g., a recycling center.

LIGNIN: Cellulose-like, organic substance which acts as a binder for the cellulose fibers in wood and adds strength and stiffness to the cell walls.

LIKE-PRODUCTS: Similar products; e.g., a glass container being recycled into the manufacturing process to make glass containers as opposed to being recycled to make terrazzo or glassphalt.

LOW-TECH SYSTEMS: Labor-intensive resource recovery systems. Recycling centers are low-tech systems.

MECHANICAL PULP (GROUNDWOOD): Pulp that is produced by mechanically grinding the wood into fibers.

METRIC TON: 2,204.6 pounds or 1,000 Kilograms.

MIXED-CULLET: A term to identify post-consumer glass containers which are not separated by color; e.g., a collection of green, amber, and flint glass.

NET-TON: 2,000 pounds (also known as a "short ton").

OBSOLETE SCRAP: Scrap available from obsolescence; e.g., old equipment, automobiles, etc.

PEROXIDES: Oxides containing an O_2 group in which two atoms of oxygen are linked by a single bond; used in the bleaching of pulp.

POST-CONSUMER CULLET: Cullet distinguished from in-house cullet because it is made of recycled glass containers that consumers have used.

POST-CONSUMER WASTES: Garbage that is generated through consumers' use of purchased products; differentiated from wastes generated by industry in processing.

PRIMARY PRODUCTION: Production of aluminum using virgin materials.

PULPWOOD: Wood used in paper production.

PROMPT INDUSTRIAL SCRAP: Steel purchased from fabrication plants.

RECYCLED: To recover from the waste stream for use in marketable products.

REDUCTION: 1. The addition of hydrogen or the abstraction of oxygen from a substance.

2. The extraction of any metal from its ore.

RESOURCE RECOVERY: A general term referring to any method of reclaiming garbage for reuse.

REVERBERATORY FURNACE: A furnace with a shallow hearth, having a roof that deflects the flame and radiates heat towards the surface of the charge. Firing may be with coal, pulverized coal, oil, or gas.

ROASTING: The heating of ore to effect some chemical change to facilitate smelting.

ROUNDWOOD: Harvested trees to be used in paper production; i.e., logs.

SAWMILL RESIDUE: The sawdust and wood chips left from sawmill operations.

SECONDARY MATERIALS: Post-consumer wastes which are integrated back into the production process.

SECONDARY PRODUCTION: Production of aluminum using used scrap and other forms of recycled aluminum.

SEPARATE CURBSIDE COLLECTION: A residential collection service of recyclable materials only.

SMELTING: Any metallurgical operation in which metal is separated by fusion from impurities with which it may be chemically combined or physically mixed, such as in ores.

SOURCE SEPARATION: The process of separating recyclables from non-recyclables at the household. The term is used loosely to apply to any labor-intensive recycling operation; e.g., curbside pick-up, delivery to recycling center, drop box recycling, hand-sorting recyclables.

"TAKE-OR-PAY" CONTRACT: A contract where the buyer agrees either to take a specified volume of materals from a resource recovery facility or to pay for its disposal.

TENSILE STRENGTH: Resistance to lengthwise stress, measured by the greatest load pulling in the direction of length that a given substance can bear without tearing apart.

THERMOMECHANICAL PULP: Pulping process in which the wood is heated, then subjected to repeated compressions and stress relaxations between opposite bars and grooves to break the wood into fibers.

VIRGIN MATERIALS: Raw materials which are extracted from natural resources for use in the manufacture of commodities.

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